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Field Studies on Paraho Retorted Oil Shale Lysimeters: Leachate, Vegetation, Moisture, Salinity, and Runoff, 1977-1980

Colorado State Univ., Fort Collins

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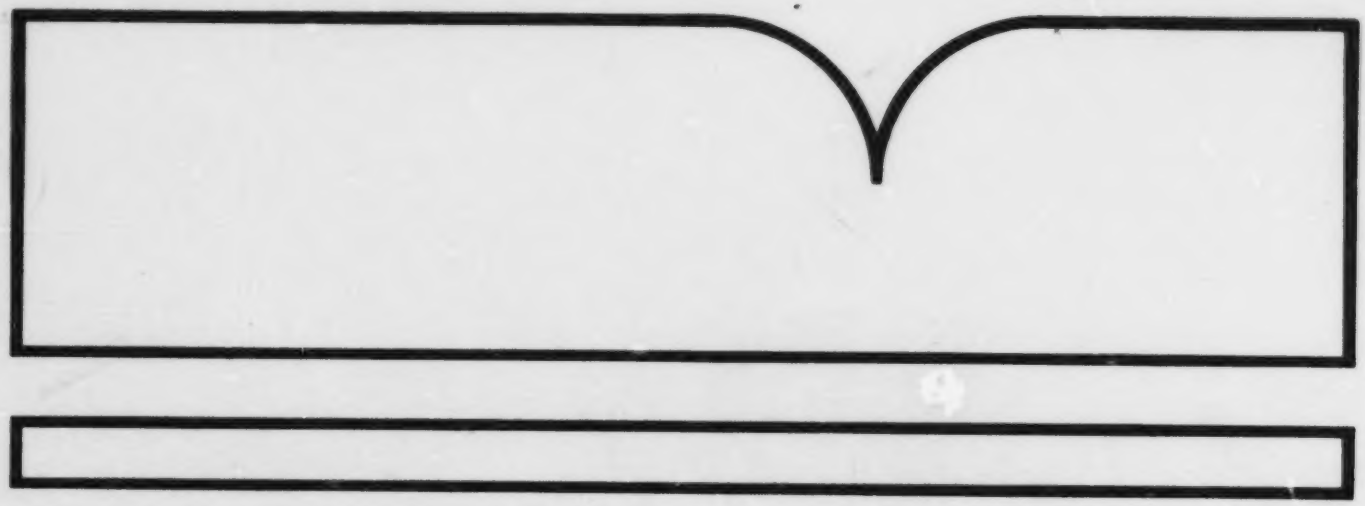

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FIELD STUDIES ON PARAHO RETORTED OIL SHALE LYSIMETERS: Leachate, Vegetation, Moisture, Salinity, and Runoff, 1977-1980

by

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16. ABSTRACT

A disposal scheme for Paraho retorted shale utilizing lysimeters to simulate a low-elevation (dry site) and a high-elevation (moist site) was constructed. Objectives of the study were to investigate 1) vegetative stabilization of Paraho retorted shale, as affected by leaching and soil cover treatments; and 2) moisture and soluble salt movement through the soil/shale profile.

After intensive management and four growing seasons, only a sparse (2% to 3%) cover of perennial vegetation resulted on the Paraho retorted shale. In contrast, good to excellent cover was established and maintained on the soil control and soil-covered retorted shale treatments.

Initial leaching and irrigation for plant establishment produced percolate from drains below the compacted shale zone. The percolate from the Paraho retorted shale treatment measured a maximum electrical conductivity (EC) of 35 mmhos/cm and pH of 11.4. The soil control produced percolate with a maximum EC of 8.5 mmhos/cm and a pH of 8.3. Each spring the high-elevation lysimeter received supplemental irrigation to simulate a zone of higher precipitation. Percolate produced from these irrigations exhibited a general overall reduction in both EC (33 to 11.4 mmhos/cm) and pH (11.4 to 8.6) by 1980 on the Paraho retorted shale treatment. The low-elevation lysimeters did not receive additional spring irrigations and no percolate was produced from the unleached treatments.

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This study used lysimeters to simulate both a low-elevation (dry site) and a high-elevation (moist site) disposal scheme for Paraho direct-heated oil shale. The study investigated the surface vegetative stabilization of retorted shale with and without soil cover and investigated water and salt movement through compacted and uncompacted Paraho retorted shale. The results should be useful to government agencies and private developers involved with developing control technology methods for retorted oil shale disposal. For more information, contact the Oil Shale and Energy Mining Branch of the Energy Pollution Control Division.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

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ABSTRACT

A disposal scheme for Paraho retorted shale utilizing lysimeters to simulate a low-elevation (dry site) and a high-elevation (moist site) was constructed. The study site was located in western Colorado at the Department of Energy oil shale research facility at Anvil Points. The lysimeters were constructed in 1976 and filled with retorted shale in 1977. Objectives of the study were to investigate 1) vegetative stabilization of Paraho retorted shale, as affected by leaching and soil cover treatments; and 2) moisture and soluble salt movement through the soil/shale profile.

After intensive management and four growing seasons, only a sparse (2% to 3%) cover of perennial vegetation resulted on the Paraho retorted shale. In contrast, good to excellent cover was established and maintained on the soil control and soil-covered retorted shale treatments.

Initial leaching and irrigation for plant establishment produced percolate from drains below the compacted shale zone. The percolate from the Paraho retorted shale treatment measured a maximum electrical conductivity (EC) of 35 mmhos/cm and a pH of 11.4. The soil control produced percolate with a maximum EC of 8.5 mmhos/cm and a pH of 8.3. Each spring the high-elevation lysimeter received supplemental irrigation to simulate a zone of higher precipitation. Percolate produced from these irrigations exhibited a general overall reduction in both EC (33 to 11.4 mmhos/cm) and pH (11.4 to 8.6) by 1980 on the Paraho retorted shale treatment. The low-elevation lysimeters did not receive additional spring irrigations and no percolate was produced from the unleached treatments. When the constructed lysimeters were filled with freshly retorted shale a high temperature (60°C) was maintained at a 1 m depth for 30 days. Prolonged, elevated temperatures of retorted shale disposal piles could significantly affect both the amount and composition of vegetative cover.

This report deals most specifically with the collection, measurement, and interpretation of data from 1978 through 1980. A more detailed description of all measurements and analyses for 1976-1977 was reported in Harbert et al. (1979).

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ABBREVIATIONS AND SYMBOLS

cm	centimeter
CSU	Colorado State University
DTPA	diethylenetriamine pentaacetic acid
EC	electrical conductivity
mmhos/cm	millimhos per centimeter
µmhos/cm	micromhos per centimeter
ha-m	hectare-meter
kg/ha	kilogram per hectare
km	kilometer
ℓ	liter
meq/ℓ	milliequivalent per liter
pH	a numerical designation of acidity and alkalinity
ppm	parts per million
SAR	sodium adsorption ratio
SD	standard deviation
$\overline{TDS}$	total dissolved solids
$\overline{X}$	mean

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SECTION I

INTRODUCTION

In recent years the need to develop new energy resources within the United States has become increasingly important. In 1973 the U.S. Department of Interior estimated that the western oil shale reserves, consisting of over 64,750 square kilometers in Colorado, Wyoming, and Utah, contained over 9.5×10^{13} ℓ (600 billion barrels) of recoverable crude oil. These previously undeveloped areas, used largely as range and wildlife habitats, will be subject to vast land disturbances with the development of an oil shale industry.

Various waste products will be generated by shale processing methods making it necessary to develop control technology in order to limit the environmental impact. One of the major environmental problems associated with oil shale development is the disposal of the massive amounts of waste material produced. The U.S. Department of Interior (1973) estimated that a mature oil shale industry of 1.6×10^{8} ℓ of oil/day (one million barrels of oil/day) would generate approximately 20,000 ha-m/year of waste material with surface retorting methods. Part of this waste might be returned to mined areas, but a large proportion would require surface disposal. Not only the large volume, but also the chemical and physical characteristics of the waste will create challenges for the development of control technology.

A part of the solution to the management of processed shales would be the rapid establishment of a satisfactory vegetative cover on disposal piles. Vegetation would stabilize the processed shale by decreasing water and wind erosion. Transpiration by vegetation would also result in less moisture available for deep percolation. Establishment of vegetation would also aid in returning the area to a valuable range and wildlife habitat, and provide a more aesthetic landscape.

To make reasonable predictions about the environmental impact of an oil shale industry it is necessary to investigate both the chemical and physical properties of the waste material. Factors affecting the characteristics of the retorted shale include the natural variation in the raw shale, the degree to which the raw shale was crushed prior to retorting and the retorting process itself.

In addition to physical and chemical characteristics of the retorted shale, the location of the disposal sites in a region of complex geomorphology and varied climatic regimes will influence the success of disposal management efforts.

Thus, the following study was initiated to evaluate a variety of intensive management techniques and practices for the disposal of processed oil shale: A model was designed to simulate the disposal of Paraho retorted shale (direct-heated) at both a low-elevation (dry site) and a high-elevation (moist site). Lysimeters were constructed to measure both the quality and quantity of percolate which might result from a processed shale disposal pile. Various treatments such as leaching and soil cover were used to investigate the establishment of vegetative cover on the Paraho retorted shale.

This report follows an initial report by Harbert et al. (1979) which detailed the construction of the lysimeters, establishment techniques, and the results of the first growing season.

SECTION II

CONCLUSIONS

CHEMICAL AND PHYSICAL CHARACTERISTICS OF PARAHO RETORTED SHALE

1. After four wetting-and-drying cycles, the pH of Paraho retorted shale surface samples was reduced from 11.2 to 9.0.

2. After leaching, the Paraho retorted shale soluble salt content was reduced from 7.1 mmhos/cm to 3-4 mmhos/cm.

3. The unleached treatments averaged approximately 10 mmhos/cm throughout the retorted shale profile, although, there was no indication of upward migration of soluble salts by 1979.

4. Laboratory analyses of 1977 core samples suggested that imbalances of calcium, magnesium, and sodium might inhibit plant growth on the Paraho retorted shale.

5. Surface temperatures reached 80°C on south slopes of the black-colored Paraho retorted shale. This might be lethal to seedlings, while increasing surface evaporation.

VEGETATION

1. After four growing seasons, perennial vegetation on the Paraho retorted shale remained minimal (2% to 3% cover).

2. A good to excellent vegetative cover was established and maintained on the soil control and soil-covered, retorted shale treatments, with western wheatgrass as the predominant species.

3. Differences between varying amounts of soil cover, with respect to vegetative cover, were insignificant.

4. Shrubs seeded on the low-elevation lysimeters were unable to significantly increase in either number or size over four growing seasons, indicating limited root tolerance for the Paraho retorted shale.

PERCOLATE

1. Ninety-nine percent of the total percolate collected from all treatments was from the lower drain, under the compacted zone.

2. Core samples taken later suggested that moisture had moved through both the uncompacted and compacted profile.

3. Abrupt textural changes from the fine-textured soil to the coarse-textured Paraho retorted shale below, delayed the uniform downward movement of moisture through the profile.

4. Irrigation (except for 1980) of the high-elevation lysimeters resulted in percolate each spring.

5. Only the treatments which had been leached (Paraho retorted shale and 20-cm soil/Paraho retorted shale) of the low-elevation lysimeters produced percolate.

6. On unleached treatments of the low-elevation lysimeters moisture did not move below 105 cm.

WATER QUALITY

1. The maximum EC of percolate from the Paraho retorted shale was 35 mmhos/cm.

2. Overall, a decrease in percolate EC after four years was observed, however, EC values fluctuated considerably.

3. If water moves through the Paraho retorted shale a high pollution potential exists, with respect to EC and SAR values measured.

4. Greater total pore volumes must pass through the lysimeters before the chemical composition of the percolate stabilizes.

DISPOSAL PILE TEMPERATURES

1. The freshly retorted shale used in this study maintained 60°C temperatures for 30 days.

2. Prolonged, elevated temperatures could significantly affect both the amount and composition of vegetative cover on disposal piles.

SECTION III

RECOMMENDATIONS

1. Because of the unsuitability of the Paraho retorted shale as a direct plant growth media, soil cover is recommended for successful establishment of vegetation on the retorted shale.

2. Poor establishment and growth of the fourwing saltbush suggested limited root penetration into the Paraho retorted shale. Additional studies are needed to evaluate root growth in retorted shale.

3. Efforts should be made to prevent movement of water through the retorted shale as leach water poses a pollution potential due to high soluble salt content.

4. Research is needed to insure that the compacted shale can be made impervious, since in this study, moisture moved through Paraho retorted shale compacted to a density of 1.5 to 1.6 g/cm^3.

5. Elevated temperatures maintained in the retorted shale disposal pile might adversely affect the establishment of vegetation. Further investigation under commercial disposal pile conditions is recommended.

6. The present fluctuations in chemical composition of leachate from the lysimeters require that additional pore volumes of water are needed to evaluate leachate quality.

SECTION IV

METHODS AND MATERIALS

In 1976 a series of concrete lysimeters were constructed to aid in modeling a disposal scheme for Paraho retorted (direct-heated) oil shale. The lysimeters were designed to simulate a canyon fill disposal site having the following features:

1. The back face of the canyon fill gently sloped (2% to 5%) upstream.
2. The front face of the dam steeply sloped (25% to 50%) downstream.
3. The body of the disposal pile highly compacted.
4. The exposed surface of either uncompacted retorted shale or soil-covered retorted shale of a sufficient depth to provide adequate plant rooting and moisture storage.

A study site was selected at the U.S. Department of Energy, Anvil Points Research Facility in western Colorado (Figure 1). The study site, on public land managed by the Bureau of Land Management, was characteristic of a semi-arid, low-elevation disposal site, with an elevation of 1737 m, and an average annual precipitation of 28 cm.

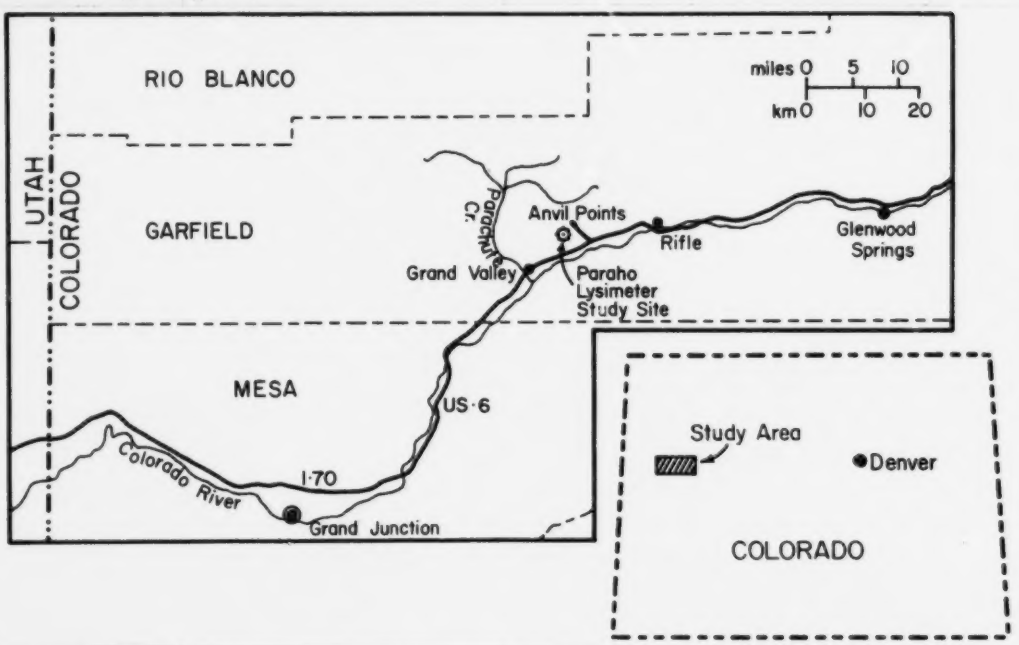


Figure 1. Location of Paraho retorted shale lysimeter study site.

Two identical sets of lysimeters were constructed at this site. One set was used to simulate the natural low-elevation site, while the other was to simulate a high-elevation disposal site. Because of proximity to water, electricity, retorted shale, and construction supplies, both sets of lysimeters were built at the low-elevation site. Sprinkler irrigations simulated the increased precipitation associated with a high-elevation site.

The following replicated treatments (shown in Figure 2) were tested with each lysimeter set, on both a 2%, north-aspect slope, and a 25%, south-aspect slope:

1. Paraho retorted shale, leached
2. 20 cm soil cover over Paraho shale, leached
3. 40 cm soil cover over Paraho shale, unleached
4. 60 cm soil cover over Paraho shale, unleached
5. 80 cm soil cover over Paraho shale, unleached
6. Soil control, unleached

Each of the treatments, except the soil control, contained 90 cm of compacted Paraho retorted shale, covered with uncompacted shale, and various amounts of soil cover (for some treatments) to equal a total profile depth of 240 cm. Drains were built into the lysimeters at both the interface of the compacted and uncompacted zones and beneath the compacted zones (Figure 3). A more detailed description of the construction of these lysimeters may be found in Harbert et al. (1979).

During the filling operation, temperature measurements of the retorted shale were made with a thermocouple probe. A series of thermocouples were later used to measure surface temperatures throughout the 1977 and 1978 growing season.

Previous research by Bell and Berg (1977) showed that the pH of Paraho retorted shale could be reduced from 11 to 9 by four wetting and drying treatments. Therefore, in April 1977, the retorted shale treatments of both lysimeters were subjected to four wet-dry cycles. Shale samples were collected before and after the procedure and analyzed for pH and EC on a 1:1 shale to water by weight extract.

The lysimeters were instrumented with tensiometers, piezometers, neutron probe access tubes, and salinity sensors to monitor the water and salt movement through the uncompacted zones. Tensiometers were installed at 15, 30, 60, 90, 120, and 150 cm depths to measure soil and shale matric potential for 1977. The tensiometer data were used by other researchers for a hydrological modeling study, and are not included in this report (Chandler, 1979). Piezometers were installed to a depth of 150 cm (the interface of the compacted and uncompacted zone) and read during the 1977 season. Neutron probe access tubes were also set to a depth of 150 cm. Monthly readings of soil moisture by volume were taken during each growing season. Salinity sensors were placed at depths of 15, 30, 60, 90, 120, and 150 cm. Because of erratic readings, the use of the sensors was discontinued in 1978.

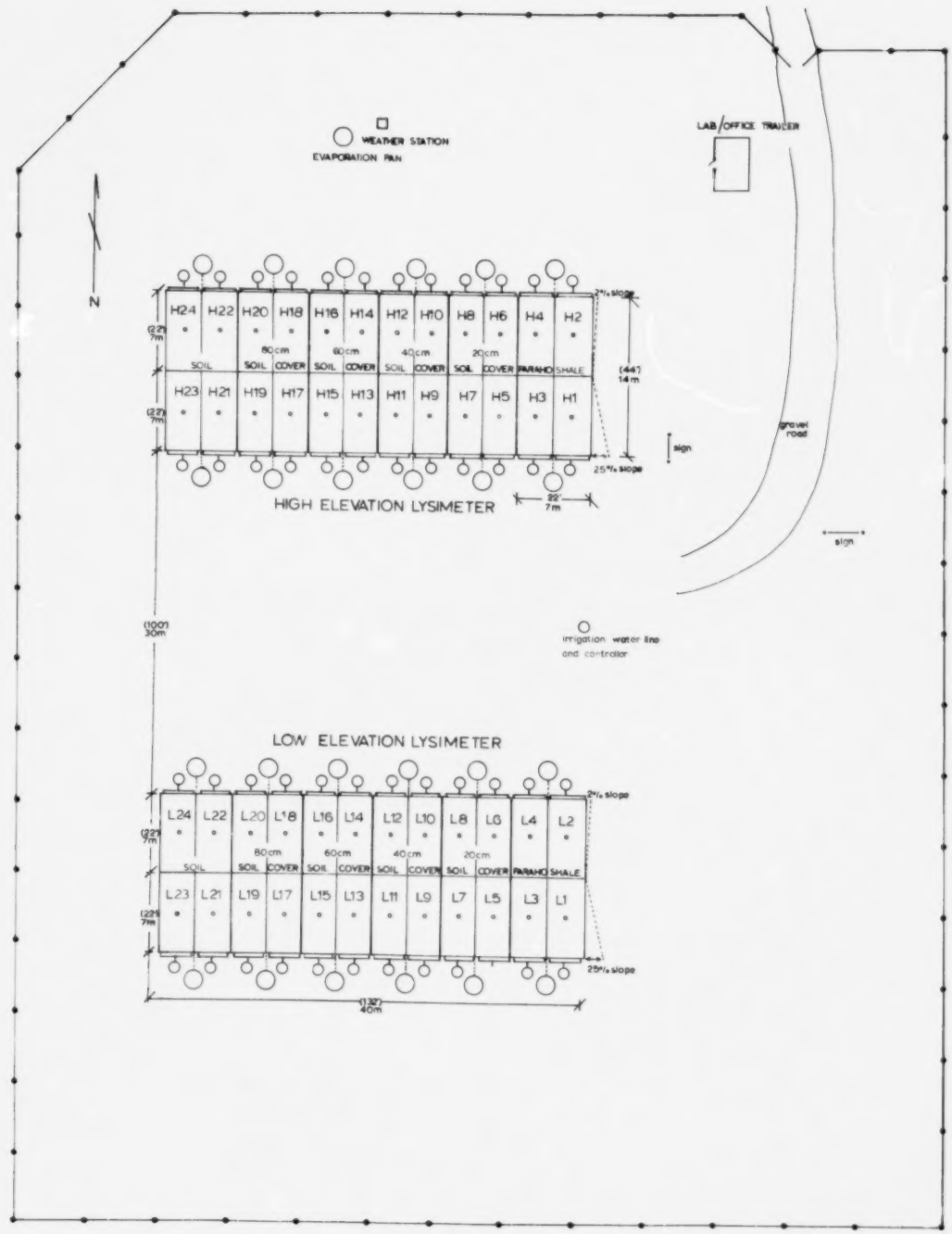
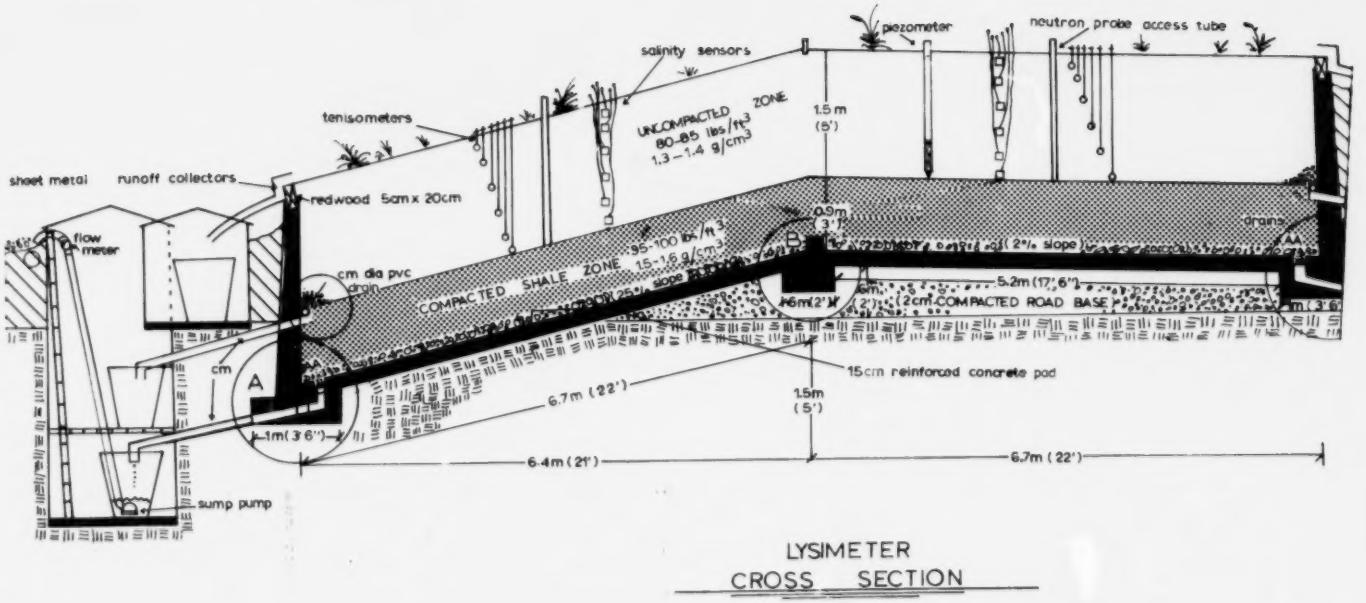


Figure 2. Diagram of the Paraho retorted shale lysimeter study treatments.



LYSIMETER
CROSS SECTION

Figure 3. Cross section of the lysimeter design.

The subsurface drain system within each treatment area was fitted with a plastic container for collecting leachate, an electric sump pump, and a totalizing flow meter to measure both the rate and volume of leachate from the lower drain. Any percolate from the upper drain, in the interface area, was collected in a plastic can.

A surface runoff collection system for each treatment plot consisted of a metal gutter, pipe, and a culvert with a plastic container. The system was completed in 1977 and used to collect snowmelt runoff and summer storm runoff of later seasons.

Before seeding, the Paraho retorted shale and the 20-cm soil cover treatments of both high- and low-elevation lysimeters were leached. Leaching was continuous, with a total of approximately 77 cm of sprinkler applied water from June 2 through June 15, 1977. Other unleached treatments were covered with plastic for this period. Any percolate resulting from this leaching was collected and analyzed by the CSU Soil Testing Laboratory. The EC and pH of percolate and irrigation water was measured periodically throughout the leaching and establishment phases.

All plots were fertilized by incorporating 168 kg P/ha as triple superphosphate into the surface 15 cm and broadcasting 67 kg N/ha as ammonium nitrate following germination. Maintenance N fertilization was done early in the growing season of each year by broadcasting ammonium nitrate at a rate of 67 kg N/ha until 1980 at which time maintenance fertilization was discontinued.

Each lysimeter was seeded June 24, 1977 with a mixture of native grasses, shrubs, and forbs. Different seed mixes were used for the high- and low-elevation lysimeters to suit the elevation modeled (Table 1). After seeding, each treatment was mulched with alfalfa hay, and covered with a plastic netting.

After seeding, a vegetative cover was established by daily sprinkler applications. The high-elevation lysimeters were irrigated at the rate of 2.0 cm/day from June 28 through August 18, 1977. This application rate, approximately 100% in excess of the pan evaporation rate, was applied to insure water movement through the lysimeters. The low-elevation lysimeter was irrigated with an approximate pan evaporation of 1.0 cm/day, over the same time period. The additional moisture applied to the high-elevation lysimeters was designed to investigate the quality and quantity of leachate which might result when seasonal precipitation exceeded evapotranspiration, at a high elevation. Supplemental irrigation, to simulate increased snowmelt, was applied to the high-elevation lysimeters in 1978 for a total of 26 cm. In the early spring of 1979 a total of 26 cm of irrigation water was again applied to the high-elevation lysimeters. However, in 1980 no additional spring irrigations was made. Since establishment irrigations in 1977, the low-elevation lysimeters have been dependent upon naturally occurring precipitation. Additional irrigations for the high-elevation lysimeters, have been planned for future hydrological studies by other researchers (Chandler, 1979).

TABLE 1. SEED MIXTURES AND RATES OF APPLICATION FOR THE LOW- AND HIGH-ELEVATION LYSIMETERS.

Common Name	Scientific Nomenclature	Rate Kg/ha
HIGH ELEVATION MIXTURE		
Species Seeded		
Western wheatgrass	*Agropyron smithii*	9.0
Bluebunch wheatgrass	*Agropyron spicatum*	4.5
Utah sweetvetch	*Hedysarum boreale utahensis*	4.5
Palmer penstemon	*Penstemon palmeri*	2.2
Lupin spp.	*Lupines spp.*	2.2
Arrowleaf balsamroot	*Balsamorhiza sagittata*	2.2
	TOTAL	24.6
Species Transplanted		
Serviceberry, Utah	*Amelanchier utahensis*	4/replication
Bitterbrush, antelope	*Purshia tridentata*	2/replication
LOW ELEVATION MIXTURE		
Species Seeded		
Western wheatgrass	*Agropyron smithii*	4.5
Bluebunch wheatgrass	*Agropyron spicatum*	4.5
Indian ricegrass	*Oryzopsis hymenoides*	4.5
Galleta	*Hilaria jamesii*	4.5
Winterfat	*Ceratoides lanata*	1.1
Fourwing saltbush	*Atriplex canescens*	2.2
Utah sweetvetch	*Hedysarum boreale utahensis*	4.5
Palmer penstemon	*Penstemon palmeri*	2.2
	TOTAL	28.0

Vegetative analysis for 1977 was done by the quadrat method, to determine vegetative cover. For vegetative measurements 1978-1980 the line-transect method was used. Vegetative cover as well as species composition was determined.

In September of 1977 core samples were taken from various treatments in 20-cm increments to a depth of 160 cm. These samples were analyzed by the CSU Soil Testing Laboratory for common cations and anions, pH, and EC. Core samples were again taken in the fall of 1979 for EC analysis.

Ambient air temperature, precipitation, and pan evaporation have been monitored since establishment of the lysimeters.

A more detailed discussion regarding all measurements and analyses for 1976-1977 was presented in an earlier report (Harbert et al., 1979). All data collected for 1978-1980 are reported in the appendix tables following this report.

SECTION V

RESULTS AND DISCUSSION

CHEMICAL AND PHYSICAL PROPERTIES OF RETORTED SHALE AND SOIL

The Paraho retorted shale and the soil used in this study were characterized as to physical and chemical properties (Table 2). Retorted shale samples were collected from the retort and analyzed daily during the lysimeter filling operation (March 21 through April 4, 1977) by Development Engineering, Inc. personnel at Anvil Points. In addition to routine analyses associated with the retorting operation, the samples were analyzed for pH and EC.

These analyses indicated that the pH of freshly retorted shale was between 11.3 and 11.6, with an EC between 2.2 and 4.3 mmhos/cm on a 1:1 by weight (water to shale) extract. A standard saturation paste was not used because the coarse texture of the retorted shale prevented an accurate determination of saturation as described for soils by the U.S. Salinity Laboratory (Richards, 1954). A rough conversion of a 1:1 extract conductivity to a saturated paste extract conductivity can be made by doubling the former value. A material is considered saline when the EC of a saturation extract is >4 mmhos/cm. Thus, freshly retorted Paraho shale was characterized as having a high pH and moderate soluble salt content. However, when the retorted shale was exposed to the atmosphere, the pH decreased and the EC increased. Samples were collected by CSU personnel in March and April 1977, air-dried and stored in plastic bags. Analyses of the Paraho retorted shale and the soil used for the various treatments in the lysimeter study are reported in Table 2.

The SAR (Sodium Adsorption Ratio) is a measure of the ratio of sodium to calcium and magnesium of soils or waters and estimates the dispersion potential posed by exchangeable sodium, when soluble salts are leached (Richards, 1954). A potential sodium dispersion problem may exist when SAR values exceed 15. The SAR value of the Paraho retorted shale (Table 2) suggested such a problem. Other analyses indicated that the retorted shale would require fertility amendments for successful vegetative growth. While plant-available phosphorus was low for the retorted shale (as well as the soil), potassium seemed adequate, but nitrate-nitrogen was low.

Physically, the soil was fine-textured (clay loam) and the Paraho retorted shale was very coarse (gravelly sandy loam). Although the retorted shale was coarse, the large particles were fairly porous and contained a reservoir of soluble salts which could present a long-term salinity problem.

TABLE 2. CHEMICAL AND PHYSICAL CHARACTERISTICS OF PARAHO RETORTED SHALE AND SOIL USED IN THIS STUDY.

Chemical Analysis	Retorted Shale* Uncompacted	Retorted Shale* Compacted	Soil Cover†
EC (mmhos/cm @ 25 C)	7.1	6.6	1.7
pH	9.7	8.9	8.2
SAR	19.0	7.9	4.7
Cations (meq/l)			
Ca	21.6	17.0	5.2
Mg	24.3	25.6	5.8
Na	91.5	43.3	11.0
K	7.1	4.9	0.1
Anions (meq/l)			
HCO_3	1.7	1.5	2.1
Cl	3.6	4.4	2.0
SO_4	131.3	83.1	13.1
CO_3	0.5	0.3	0.4
O.M. (% Organic-C) (Walkley-Black method)	4.0	4.0	1.8
P, ppm ($NaHCO_3$ extraction)	2	1	3
K, ppm (NH_4 acetate extraction)	383	315	74
NO_3-N, ppm (KCl extraction)	2	2	6
Zn, ppm (DTPA extraction)	9.9	9.6	2.6
Fe, ppm (DTPA extraction)	225.6	215.3	5.2
Textural Analysis ‡			
Gravel % <2 mm	90.5	47.8	38.7
Sand % <0.074 mm	5.2	27.6	22.5
Silt % <0.005 mm	2.9	17.2	20.8
Clay % <0.005 mm	1.4	7.4	17.8

* Retorted shale analyses were on 1:1 extracts for EC, pH, SAR, cations, and anions.

† Soil analyses were on saturation extracts for EC, pH, SAR, cations, and anions.

‡ Values are means of four replications, analysis of <2 mm particles was by the hydrometer method.

The importance of the textural difference between the retorted shale and the soil is discussed further in the moisture and percolation sections which follow. Physical characteristics such as texture were altered significantly by compaction of the retorted shale. About 90% of the uncompacted shale was >2 mm sized (gravel), but after compaction, only 48% of the shale remained gravel sized (Table 2). Holtz (1976) also reported a reduction in the particle size of Paraho retorted shale with compaction.

Wet-Dry Cycles

After filling of the lysimeters was completed, a series of wetting and drying cycles were used to reduce the pH of the retorted shale. Although the pH was successfully reduced from 11.4 to 9.2, the EC increased from 4 to 6.1. The increase in EC was probably due to the greater solubility of Ca and Mg salts at a lower pH.

Apparently, the amount of carbonate decomposition was minimal with the Paraho direct retorting process, and this allowed rapid recarbonation of the retorted shale. The pH of the retorted shale would likely have decreased with the natural weathering process. The amount of carbonate decomposition with retorting has both advantages and disadvantages in terms of disposal. If the carbonate decomposition was low, the pH would decrease rapidly. But, if more carbonates were converted to oxides during retorting, the pH would remain elevated and the retorted shale might have a cementing quality. The cementing could provide greater pile stability and reduce water movement through the disposal pile. Highly cemented shales would require deeper soil covers to insure adequate moisture storage for perennial vegetation.

Retorted Shale Temperatures

Temperatures of the retorted shale in the uncompacted zone were monitored with a thermocouple probe following the filling of the lysimeters in 1977. Although a sharp drop in the temperature of the shale (230 to 64-80°C) occurred within 10 days after placement, an additional 30 days was required for the shale to drop below 60°C at the 1 m recording depth (Figure 4). During a snowstorm on April 5, 1977, it was observed that 10 cm of snow accumulated on the soil control and surrounding area. However, snow falling on the retorted shale and soil-covered retorted shale, melted. No snow remained even on the 80 cm soil-covered retorted shale treatment. This suggested that a droughty site could develop if freshly retorted shale was covered with soil before cooling. A xeric site would significantly affect both the amount and composition of vegetation cover.

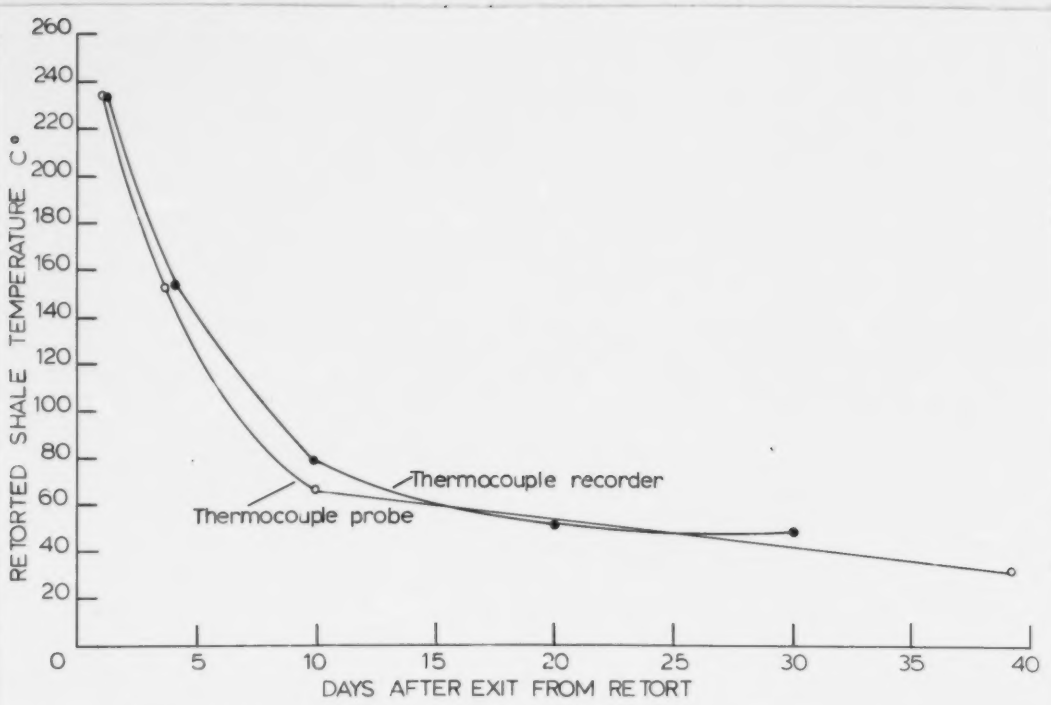


Figure 4. Cooling rates for Paraho retorted shale. Temperatures were measured at 1 m depth, with either a thermocouple recorder or probe, April 5 through May 15, 1977.

PRECIPITATION

A tipping bucket rain gauge with a continuous chart recorder was installed on the lysimeter study site. A 10-cm diameter plastic dump gauge was also located nearby. Neither precipitation gauge was wind shielded, therefore, loss of precipitation in the form of snow during winter months was expected. Precipitation for 1977 to 1980 is recorded in Table 3. The average annual precipitation for this site was estimated to be 28 cm, based on long-term precipitation data from Rifle, Colorado.

During vegetative establishment in 1977, a sprinkler irrigation system provided adequate moisture for both high- and low-elevation lysimeter studies. In the following years only the low-elevation lysimeters were dependent upon natural occurring precipitation, since supplemental irrigation was used to simulate increased moisture for the high-elevation lysimeters.

TABLE 3. MONTHLY PRECIPITATION (cm) FOR THE LYSIMETER STUDY SITE. 1976 THROUGH 1980.

Month	Paraho Lysimeter Study				
	1976	1977	1978	1979	1980
	- - - - - - - - - - - - - - - - cm - - - - - - - - - - - - - - - -				
January	0.4	1.5	4.8	0.7	5.5
February	5.9	0.6	3.5	4.5	9.2
March	3.7	2.2	9.2	3.3	4.9
April	3.4	0.9	3.4	0.6	2.1
May	4.0	1.5	2.6	4.1	6.4
June	1.8	0.5	0.6	1.2	0.0
July	1.2	-	0.2	1.7	3.0
August	2.5	4.8	1.1	3.3	2.2
September	3.8	3.7	2.0	0.4	0.6
October	1.4	2.2	0.1	2.0	4.8
November	0.1	-	5.1	3.0	1.5
December	0.1	2.5	2.9	0.6	1.6
TOTAL	28.3	20.4	35.5	25.4	41.8

- Incomplete data.

VEGETATION

In August of 1977, the first growing season, a quadrat method was used to visually estimate percentage of vegetative cover on all treatment plots. A good to excellent (55% to 85%) vegetative cover was measured on both the high- and low-elevation lysimeter soil cover treatments. A sparse (5% to 15%) vegetative cover on the Paraho retorted shales was measured (Table 4). The lack of vegetation on the Paraho shale was thought to be due to a combination of high pH, excess salinity, and high surface temperatures of the black material. Western wheatgrass was the predominant component of the vegetative cover on the high-elevation lysimeters. On the low-elevation lysimeters a dense cover of galleta, a warm season grass, dominated all other species seeded. Irrigation of both high- and low-elevation lysimeters the first growing season was used to insure a satisfactory vegetative cover. Unfortunately this stimulated a severe infestation of alfalfa and plantain, from seed in the mulch, on both sets of lysimeter plots. In later years, only the high-elevation lysimeter received supplemental irrigation to simulate a moist disposal site.

TABLE 4. VEGETATIVE COVER FOR PARAHO RETORTED SHALE, SOIL-COVERED PARAHO RETORTED SHALE, AND SOIL CONTROL, 1977-1980.

Treatment	High-Elevation Lysimeter							
	2% Slope North Aspect				25% Slope South Aspect			
	1977*	1978†	1979†	1980†	1977	1978	1979	1980
	- - - - - - - - - - - - - - - - - - % - - - - - - - - - - - - - - - - - -							
Paraho Retorted Shale	15.0	49.0	49.0	47.9	10.0	48.5	54.2	38.6
20 cm Soil Cover/Paraho	65.0	62.0	82.8	45.2	65.0	83.0	89.7	52.1
40 cm Soil Cover/Paraho	65.0	61.5	90.6	41.6	75.0	88.5	89.4	55.1
60 cm Soil Cover/Paraho	80.0	53.5	82.9	54.9	65.0	80.0	84.7	48.9
80 cm Soil Cover/Paraho	80.0	56.5	84.5	47.4	75.0	87.0	82.9	53.2
Soil Control	60.0	99.0	96.5	32.4	55.0	97.0	96.7	30.4

Treatment	Low-Elevation Lysimeter							
	2% Slope North Aspect				25% Slope South Aspect			
	1977*	1978†	1979†	1980†	1977	1978	1979	1980
	- - - - - - - - - - - - - - - - - - % - - - - - - - - - - - - - - - - - -							
Paraho Retorted Shale	5.0	14.5	25.1	26.1	5.0	21.0	29.4	17.0
20 cm Soil Cover/Paraho	70.0	65.0	91.4	73.4	85.0	66.5	58.7	65.7
40 cm Soil Cover/Paraho	70.0	63.0	90.0	67.4	80.0	60.5	68.0	61.0
60 cm Soil Cover/Paraho	85.0	71.0	80.6	61.1	80.0	59.5	82.8	52.1
80 cm Soil Cover/Paraho	80.0	70.5	69.0	57.6	80.0	57.0	70.7	53.7
Soil Control	80.0	82.5	86.0	53.0	75.0	83.0	82.6	46.5

* Values are means of six quadrats in each of two replications, 1977.

† Values are means of 3 transect-lines in each of two replications, 1978, 1979, and 1980.

The quadrat method was used for the first year of growth in 1977 to estimate germination and establishment. The line-intercept method was used in later years to provide more quantitative measurements. Because of the ample supply of water provided by the establishment irrigations, combined with high over-winter precipitation, the alfalfa and plantain infestation from the mulch increased on almost all treatment plots, particularly the high-elevation lysimeters. Many of the seeded natives were forced out due to the aggressive growth of the alfalfa and plantain. Various methods to eradicate these species were used. Hand pulling and digging, combined with carefully administered applications of 2,4-D succeeded in virtually eliminating these species from the treatment plots. Hand seeding of native species into bare areas, produced by eliminating alfalfa and plantain, was done in the fall of 1978. Although perennial vegetative cover increased on almost all high-elevation lysimeters in 1978, there was an observable decrease on

the low-elevation lysimeter plots (Table 5). This drop was due to the apparent loss of dense stands of galleta from winter-kill. Die-back of many fourwing saltbush was also observed on the low-elevation plots. The void created was readily filled by the invasion of cheatgrass on these plots. The Paraho retorted shale continued to produce only a minimal vegetative cover, consisting primarily of annual species such as Russian thistle, kochia, and chenopodium (Table 5).

Vegetative analysis in 1979 revealed that the most significant difference between treatments regarding cover was the Paraho retorted shale treatment. This treatment consistently averaged below all others with regard to vegetative cover (Table 4). More importantly the predominance of annual sepcies over perennial plants indicated that after three years of weathering, the retorted shale remained a poor plant growth medium. When the retorted shale was covered with as little as 20 cm of soil the vegetative cover increased substantially, with an accompanying increase in perennials. However, there was little observable difference between the varying amounts of soil cover with regard to vegetative cover (Table 4). The soil control supported almost a closed stand of western wheatgrass on the high-elevation lysimeters, with very little diversity of other species. The most surprising occurrence was the reappearance of large amounts of galleta on the low-elevation treatments. Evidently much of this warm season grass was able to persist through the winter. Although very little alfalfa or plantain remained on any treatment, a large amount of cheatgrass cover was present, particularly on the low-elevation plots.

In 1980, no supplemental irrigation of the high-elevation lysimeter plots was made. Consequently, vegetative cover decreased on all treatments (Table 4). Ground cover, composed of not only live vegetation but litter from previous year, combined to result in an average of less than 6% bare, exposed, surface for all soil covered treatments. On the other hand, the Paraho retorted shale treatments supported only a very minimal (2% to 3%) perennial vegetative cover (Table 5). Observations of the few perennial species on the Paraho shale indicated severe stunting and physiological stress. Caution must must be advised when comparisons of total vegetative cover between the Paraho retorted shale and other treatments are made. Values as high as 48% vegetative cover on the Paraho retorted shale, 2%-slope, north-aspect of the high-elevation lysimeters must be carefully scrutinized. This vegetative cover was almost completely composed of annual species such as kochia. This annual was at its vegetative peak when measured and with its extremely short-lived habit, left the treatment almost totally bare and exposed by mid- to late summer.

After four growing seasons the inability of shrubs (where seeded, on the low-elevation lysimeters) to either increase in number or size was observed on the soil-covered Paraho retorted shale treatments. In fact, die-back of many fourwing saltbush was previously noted. Perhaps, despite the initial growth of the shrubs in the soil cover, plant roots were unable to tolerate the Paraho retorted shale below. This phenomenon has been observed by others working with soil covers over Paraho retorted shale (Cook and Redente, 1980).

TABLE 5. VEGETATIVE COVER BY SPECIES COMPOSITION FOR PARAHO RETORTED SHALE, SOIL-COVERED PARAHO RETORTED SHALE, AND SOIL CONTROL, 1978-1980.

Treatment	Species Categories	High-Elevation Lysimeter					
		2% Slope North Aspect			25% Slope South Aspect		
		1978	1979	1980	1978	1979	1980
		%					
Paraho Retorted Shale	Perennial grasses	19	5	3	14	6	2
	Shrubs	2	-	-	-	-	-
	Other	29	46	48	26	48	39
20 cm Soil Cover/Paraho	Perennial grasses	59	72	31	60	71	47
	Shrubs	-	-	-	-	-	-
	Other	2	11	15	8	21	9
40 cm Soil Cover/Paraho	Perennial grasses	57	63	32	49	65	46
	Shrubs	-	-	-	-	-	-
	Other	5	39	13	4	30	16
60 cm Soil Cover/Paraho	Perennial grasses	47	60	43	44	67	40
	Shrubs	-	-	-	-	-	-
	Other	7	29	24	5	31	13
80 cm Soil Cover/Paraho	Perennial grasses	40	59	29	39	73	46
	Shrubs	-	-	-	-	-	-
	Other	16	27	22	10	26	11
Soil Control	Perennial grasses	86	93	33	73	95	29
	Shrubs	-	-	-	-	-	-
	Other	14	2	-	19	2	2

Treatment	Species Categories	Low-Elevation Lysimeter					
		2% Slope North Aspect			25% Slope South Aspect		
		1978	1979	1980	1978	1979	1980
		%					
Paraho Retorted Shale	Perennial grasses	8	<1	<1	2	<1	-
	Shrubs	1	1	2	5	3	3
	Other	6	24	24	15	27	19
20 cm Soil Cover/Paraho	Perennial grasses	42	18	7	26	31	23
	Shrubs	2	2	1	3	-	-
	Other	23	80	61	39	38	48
40 cm Soil Cover/Paraho	Perennial grasses	45	28	12	41	20	17
	Shrubs	<1	-	-	2	<1	2
	Other	18	69	59	19	61	47
60 cm Soil Cover/Paraho	Perennial Grasses	39	22	13	47	16	12
	Shrubs	3	3	2	<1	<1	-
	Other	29	62	51	12	79	43
80 cm Soil Cover/Paraho	Perennial grasses	59	48	25	45	22	13
	Shrubs	3	2	4	2	<1	1
	Other	8	24	33	11	57	43
Soil Control	Perennial grasses	45	51	20	61	52	22
	Shrubs	4	6	3	15	18	10
	Other	33	29	30	8	14	20

- This species category was not observed on line-transects used for analyses of vegetation.

Trace Elements in Vegetation

In 1977 and 1978 plant samples were collected from the lysimeter plots for trace element analyses. Large stands of alfalfa were present as a result of seed introduced with the hay mulch, so this species was sampled. Overall, molybdenum levels of plants from Paraho retorted shales were judged to be high (11.5 to 23.5 ppm Mo) (Kilkelly and Lindsay, 1979). This, combined with low to moderate copper levels could limit the use of this vegetation for animal forage.

Studies on other processed shales (Kilkelly, 1979) indicated that levels of boron ranging from 85 to 202 ppm B in western wheatgrass from TOSCO II retorted shales could limit the success of revegetation efforts. This study also suggested that high molybdenum levels, measured in fourwing saltbush grown on USBM retorted shales (averaging 28 ppm Mo), could make this species unacceptable forage.

Schwab et al. (1980) analyzed plants growing on Paraho retorted shales, at another study site. Levels of molybdenum in some plant species were sufficiently elevated (approximately 26 ppm) to be of concern.

MOISTURE

In 1977, during the establishment of these study plots, the Paraho retorted shale and the 20-cm soil/Paraho were leached by sprinkler irrigation to reduce problems of plant growth due to the high pH and salinity of the Paraho retorted shale. Approximately 77 cm of leach water was applied to these treatments between June 2 through June 15, 1977. Additional amounts of water were also used for plant establishment on all treatments. The high-elevation lysimeter plots received approximately twice the establishment water that was applied to the low-elevation lysimeter plots. These differences were designed to study the quality of the percolate which might result when seasonal precipitation exceeded evapotranspiration.

High-Elevation Lysimeters

Once the Paraho retorted shale and 20-cm soil/Paraho were leached, an additional amount of water was applied to all treatments for plant establishment in 1977. To simulate a zone of higher seasonal precipitation than evapotranspiration, approximately 84 cm of water was applied. During this time percolate from the lower drains of leached treatments indicated that moisture was moving through both the uncompacted and lower compacted zones. Because of the textural discontinuity that existed between the fine soil and coarse-textured Paraho retorted shale, water did not uniformly move through the profile (Figure 5). Instead, the soil cover became highly saturated (approximately 50% by volume) before water moved into the larger pores of the coarse-textured Paraho retorted shale and percolate from the lower drains resulted. Because of this; equilibrium, with respect to moisture throughout the entire profile, was not obtained by the end of the 1977 growing season.

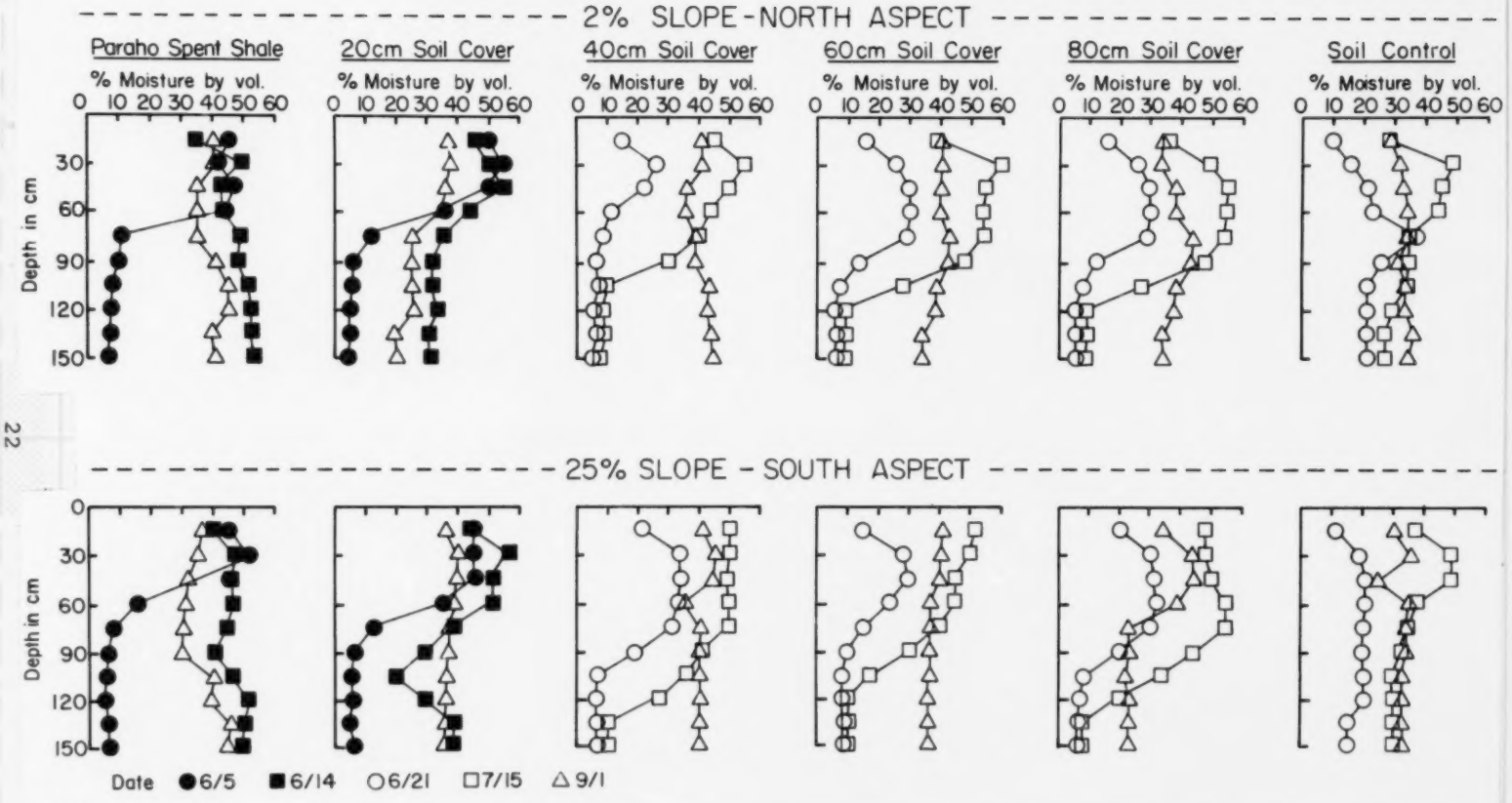


Figure 5. Seasonal moisture profiles for the high-elevation lysimeter treatments, 1977.

Again, in the spring of 1978, an application of water was made to simulate the extra snowmelt at higher elevations. Approximately 20 cm of water was applied April 10, 1978, followed by two more applications of 3 cm each; May 9 and June 27. This, in combination with above average over-winter precipitation, provided a maximum recharge of the moisture profile (20% to 25%) to the extent that percolate was collected from the lower drain of almost all treatments. Core samples taken May 3, 1978 (Table 6) also verified that water was moving through the compacted zone. By this time, the growth of vegetation on the plots was beginning to extract substantial amounts of moisture from the profiles (Figure 6). The growth of alfalfa and plantain, brought in unintentionally with the mulch, was extraordinary because of the supply of moisture stored in the profile. These species were preventing the establishment of the native species seeded on the plots and consequently were

TABLE 6. PERCENT MOISTURE BY WEIGHT OF CORE SAMPLES FROM THE LYSIMETER STUDY. May 3, 1978.

Depth (cm)	Treatment Sampled			
	High Elevation			Low Elevation
	Shale *Plot 2*	Shale *Plot 4*	40 cm Soil Cover *Plot 12*	60 cm Soil Cover *Plot 13*
0- 15	24.4	20.8	12.7	10.3
15- 30	22.9	17.9	13.5	10.3
30- 45	21.1	21.4	14.2	11.8
45- 60	25.6	19.9	15.7	15.4
60- 75	17.9	21.8	21.4	13.3
75- 90	26.3	18.1	15.3	14.8
90-105	21.8	17.5	18.4	9.9
105-120	22.8	16.8	22.7	2.1
120-135	18.7	18.9	23.7	
135-150	19.7	17.6	22.7	
150-165	23.1	20.1	20.5	3.4
165-180	22.0	20.8	22.5	4.2
180-195	20.6		22.9	
195-210				
210-225				
225-240	23.4			

* Dashed line indicates the interface of the uncompacted and the compacted zones.

eradicated, but not before considerable amounts of moisture were used. By the fall of 1978, moisture levels of treatments supporting a good stand of vegetation were reduced to approximately 10% by volume. The Paraho retorted shale, despite leaching, supported only a minimal vegetative cover, with a large percentage of weedy annuals. Therefore, moisture levels remained somewhat higher (approximately 12% to 15% by volume) than in other treatments (Figure 6).

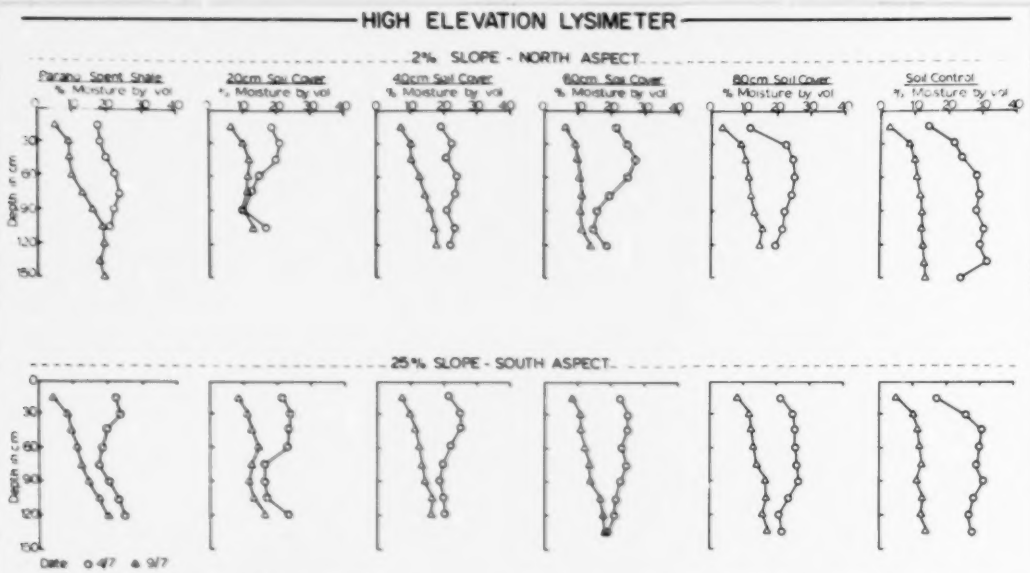


Figure 6. Seasonal moisture profiles for the high-elevation lysimeter treatments. 1978.

On April 4, 1979, 20 cm of water was applied to supplement the seasonal precipitation of the area. Approximately 3 cm of water was also applied on May 21 and again on June 18, 1979. Spring recharge of the moisture profiles averaged approximately 20% moisture by volume. Moisture recharge and extraction patterns were similar to the previous year. The soil control measured the greatest moisture use by plants during the 1979 growing season; whereas, the Paraho retorted shale with little vegetative cover, measured much less moisture loss (Figure 7).

Additional irrigations to simulate increased moisture for the high-elevation lysimeters were not made in the spring of 1980. Despite this, moisture profiles for almost all treatments continued to average spring recharge values of approximately 20% moisture by volume (Figure 8). Overwinter and early spring precipitation was slightly above average and may have accounted for recharge values similar to previous years with irrigation. By fall, moisture levels were depleted by the vegetation to approximately 10% by volume (Figure 8). The least amount of moisture use was by the sparse vegetation on the Paraho retorted shales, a large percentage of which was probably due to evaporation rather than transpiration.

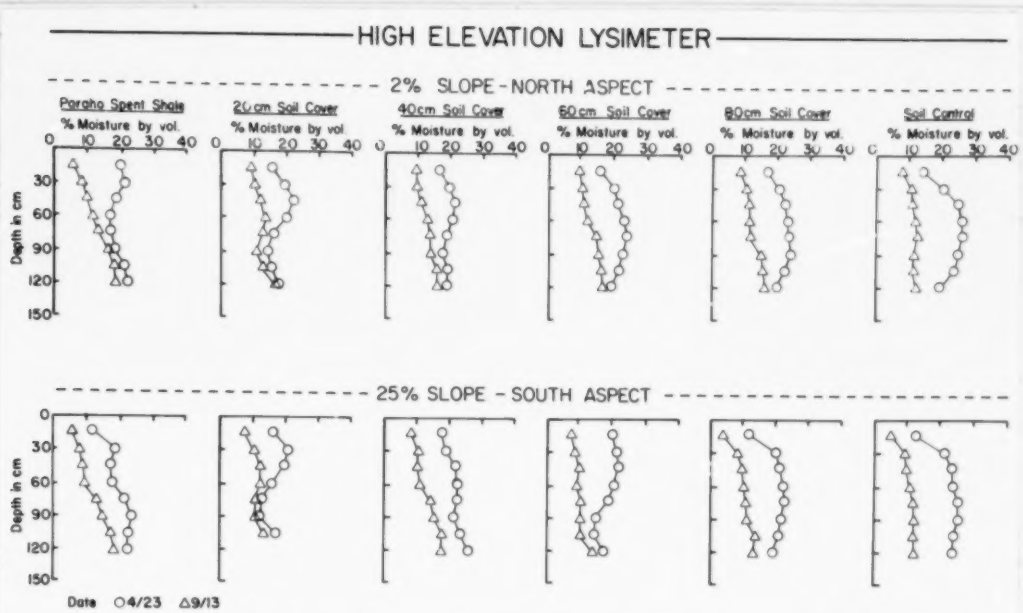


Figure 7. Seasonal moisture profiles for the high-elevation lysimeter treatments, 1979.

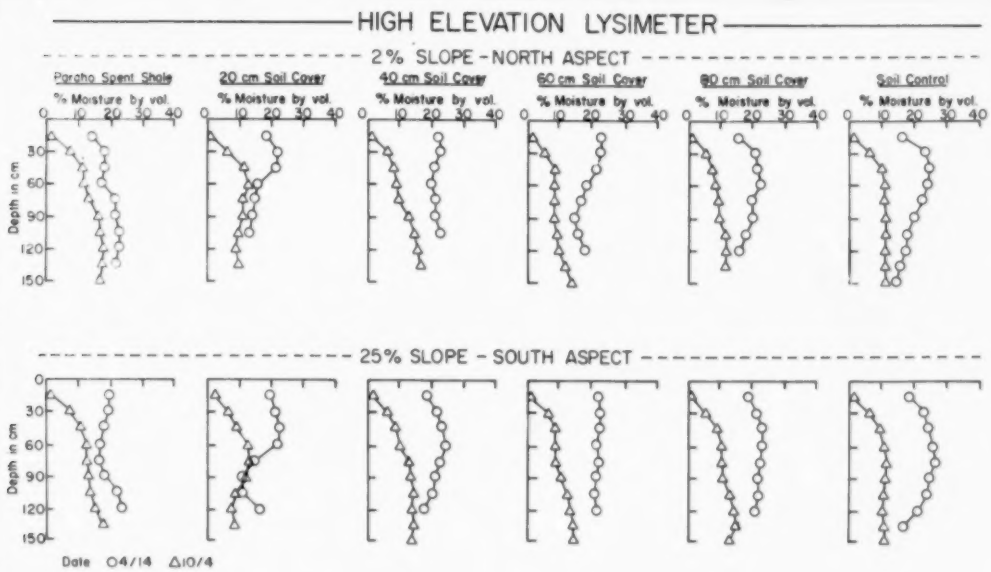


Figure 8. Seasonal moisture profiles for the high-elevation lysimeter treatments, 1980.

Each year, since establishment, irrigation of the high-elevation lysimeters produced percolate from the lower drain of most treatments. The purpose of the extra irrigation was to simulate a region of higher elevation, where seasonal precipitation exceeded the evapotranspiration of the native plant community. The collection and analysis of percolate from these treatments could then be used for predicting the potential for environmental pollution.

The Paraho retorted shale, despite leaching, continued to support far less vegetative cover than other treatments, thereby reducing the extraction of surplus moisture in the profile. Moisture recharge and depletion patterns between other treatments were similar, with the greatest amount of moisture use by the dense vegetative cover on the soil control.

Low-Elevation Lysimeters

In 1977, after the initial leaching of the Paraho retorted shale and 20-cm soil/Paraho treatments, a supplement irrigation of all treatments with approximately 37 cm of water aided in vegetative establishment. No additional irrigation was intended for future years. Other studies (Harbert and Berg, 1978) have shown that at low-elevation disposal sites moisture would not be likely to move through the entire uncompacted shale profile. An adequate vegetative cover would deplete moisture in the upper zone, allowing sufficient storage of snowmelt from year to year. During the establishment irrigation in July, water was applied slightly in excess of evapotranspiration and some percolate was measured from treatments that had received water for leaching earlier. By August, a greater vegetative cover began to deplete excess moisture from the profile, and by September 1977, water penetration into the profile of unleached soil cover treatments was limited to a depth of 105 cm (Figure 9).

Over-winter precipitation was above average for the 1977-1978 season; therefore, moisture measurements made in April of 1978 indicated a recharge of approximately 20% moisture by volume of treatments on the 2% north-aspect and 25% moisture by volume of treatments on the 25% south-aspect (Figure 10). Greater runoff of snowmelt recorded for the north-aspect decreased the amount of snowmelt that entered the profile. Additional irrigation was not provided for these treatments, and by September 1978, the moisture in the profile had been reduced to about 10% by volume on all treatments, by evapotranspiration.

Recharge and extraction patterns for the 1979 growing season were similar to 1978 observations. Over-winter precipitation recharged all treatments to approximately 20% moisture by volume. Once again, by the fall of 1979, moisture was reduced to approximately 10% by volume, to a depth of 60 cm, on those plots having a satisfactory vegetative cover (Figure 11). Less moisture was extracted from the Paraho retorted shale profile because of a less than adequate stand of native vegetation.

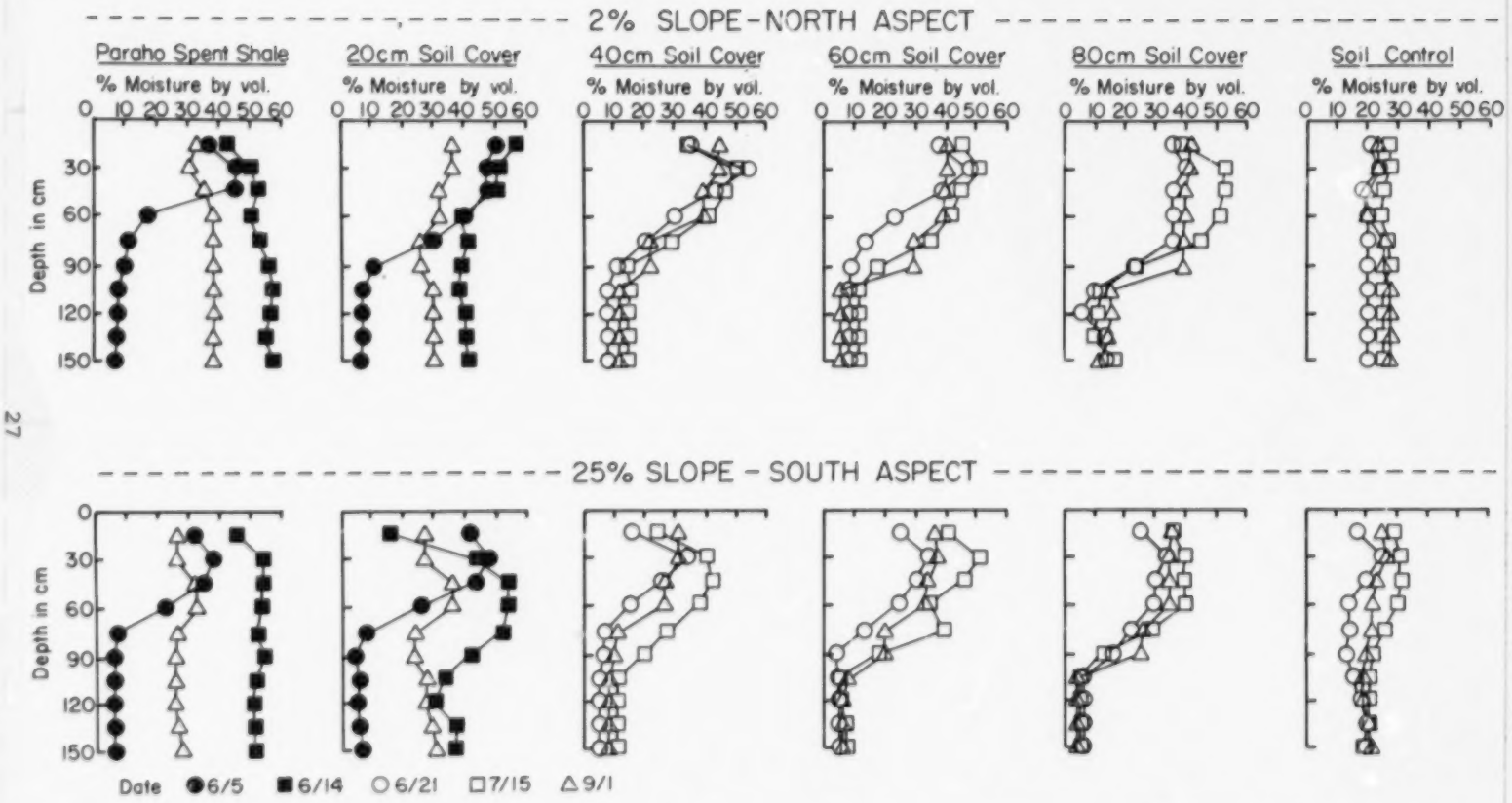


Figure 9. Seasonal moisture profiles for the low-elevation lysimeter treatments, 1977.

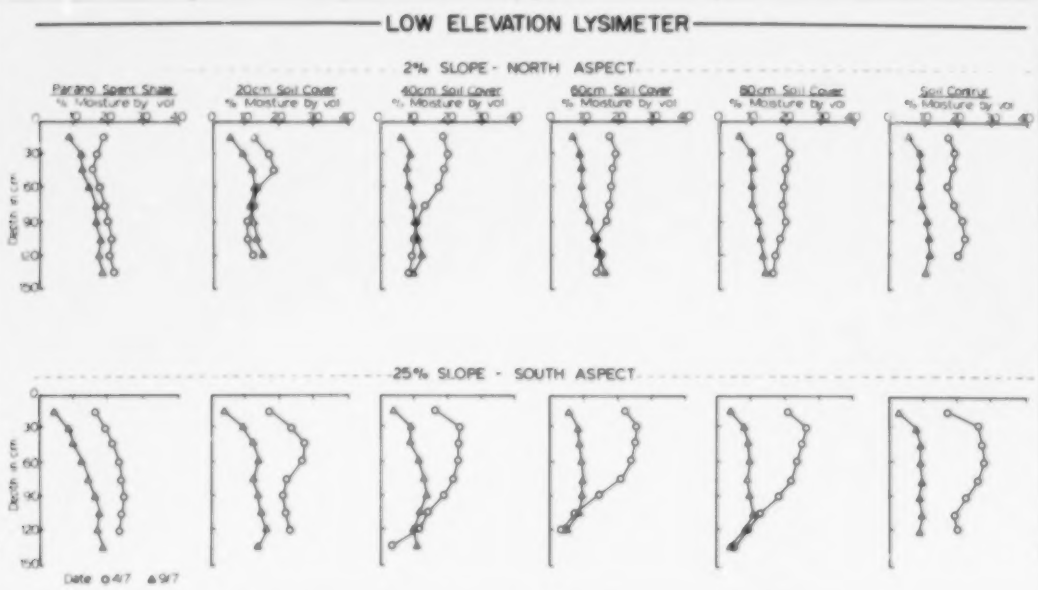


Figure 10. Seasonal moisture profiles for the low-elevation lysimeter treatment, 1978.

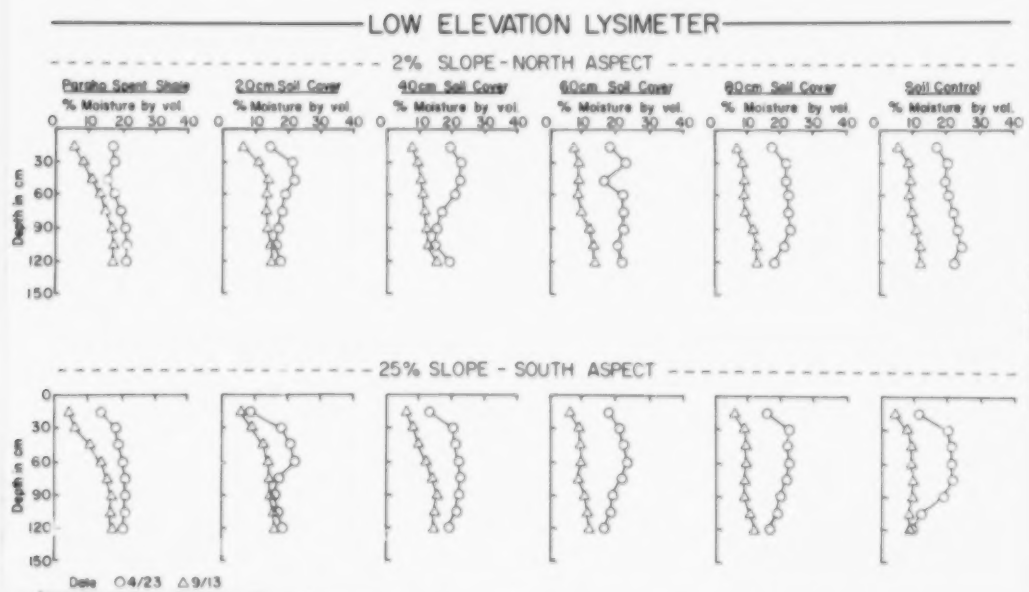


Figure 11. Seasonal moisture profiles for the low-elevation lysimeter treatment, 1979.

1980 moisture measurements indicated spring recharge values of approximately 20% moisture by volume on most treatments, with overall patterns similar to previous years. The least amount of spring moisture was contained in Paraho retorted shale profiles (Figure 12). Although runoff was not considerably greater for those treatments, moisture evaporation from the exposed black surface was most likely appreciable. Evapotranspiration reduced all treatments to approximately 10% moisture by volume by the end of the growing season. The good vegetative cover on the soil control extracted more moisture from the profile than other treatments.

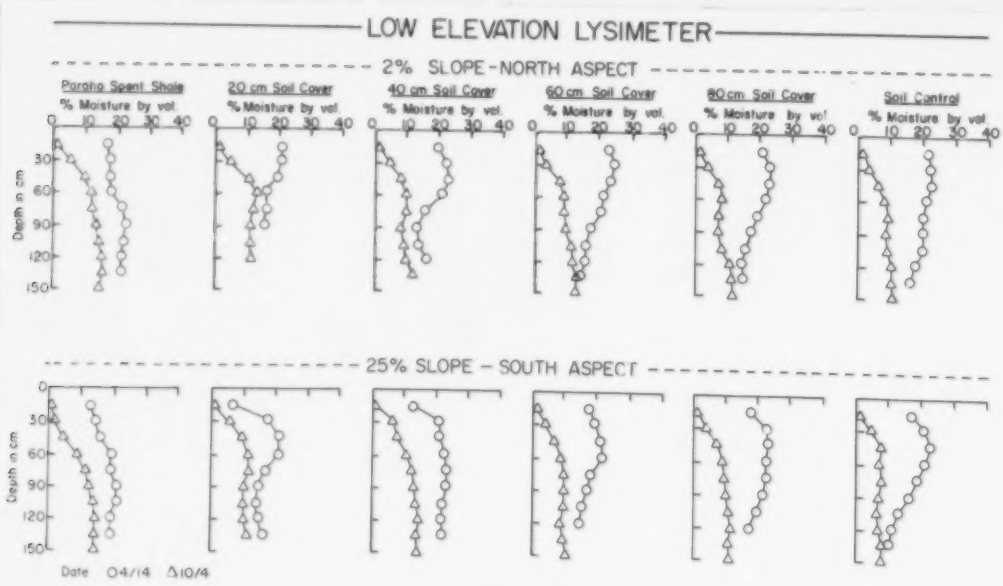


Figure 12. Seasonal moisture profiles for the low-elevation lysimeter treatments. 1980.

...ion where seasonal precipitation seldom exceeds evapotran... ...ion, and water movement within a pile of retorted shale sho... ... provided a satisfactory vegetative cover exists. In this stu... ...ecipitation over a four-year period provided a spring rech... ...oximately 20% moisture by volume (to depths of 60 to 120 cm). T... ...ents with a good vegetative cover were reduced to approximatel... ...sture by volume by fall. The moisture extracted during the growing season by vegetation resulted in a renewal of reservoir capacity to contain yearly precipitation, especially spring snowmelt. Without satisfactory vegetative cover, moisture within the profile could be moved downward with each yearly recharge, and pollution of ground water could result.

RUNOFF

1978 was the first year runoff samples were collected from the newly established lysimeters. Observations on February 28, 1978 indicated only a trace of runoff from south slopes and none from north slopes. When the collection system was next checked on March 23, 1978, it was found that moisture seeping through the seams of the galvanized steel culverts had floated the plastic runoff containers. The small amount of runoff was then contaminated by the large volume of seepage water. Only three plastic containers remained upright with uncontaminated samples (Table 7) all of which were of low salinity hazard. The culverts were sealed during the summer of 1978 to prevent further seepage.

Runoffs from south slopes of both high- and low-elevation lysimeters were measured and samples collected on March 8, 1979. At the time all north slopes remained snow covered. Measurement and collection of runoff from the north slopes was not accomplished until March 22, 1979. Recorded runoff for south slopes was greater than for north slopes. Due to the fact that snowmelt was slower on the north side, and the slope more gradual, less runoff resulted. Both pH and EC were measured in the field for samples collected March 8, 1979. However, only EC is reported in Table 8 because equilibration of the pH electrode in solution ranging from 4 to 8 C was exceedingly slow. Samples of runoff collected on March 22 were sent to the CSU Soil Testing Laboratory for water quality analyses (Table 9). The salinity hazard for all samples was low to medium, while the sodium hazard was low.

Spring snowmelt in 1980 resulted in runoff only from north slopes (Table 10). Field observations at the time of sample collection indicated that the ground on the north slopes was frozen with a thin covering of ice. The south slope ground was thawed, allowing moisture to enter the soil or shale, resulting in little runoff. This was confirmed by the water quality analyses done by the CSU Soil Testing Laboratory. The low sodium and salinity hazard combined with the negligible sediment yield suggested that the runoff never actually came in contact with the soil or shale surface, but merely ran over the layer of ice. No runoff from summer storms resulted.

TABLE 7. SPRING SNOWMELT RUNOFF FROM THE LOW-ELEVATION LYSIMETER, SOUTH-ASPECT, 25% SLOPE, MARCH 23, 1978.

Treatment	Plot #	EC	Salinity Hazard
		µmhos/cm	
Soil Control	L23	130	low
80 cm Soil/Paraho	L17	140	low
60 cm Soil/Paraho	L15	300	low

TABLE 8. SPRING SNOWMELT RUNOFF FROM THE HIGH-ELEVATION AND LOW-ELEVATION LYSIMETERS, SOUTH-ASPECT, 25% SLOPE, MARCH 8, 1979.

	Paraho Retorted Shale		20 cm Soil/ Paraho		40 cm Soil/ Paraho		60 cm Soil/ Paraho		80 cm Soil/ Paraho		Soil Control	
	H1	H3	H5	H7	H9	H11	H13	H15	H17	H19	H21	H23
Runoff (cm)	0.42	1.58	0.85	0.64	0.37	0.51	0.84	0.70	0.74	0.94	0.98	1.68
EC (μmhos/cm)*	180	180	110	180	140	90	310	510	680	190	250	150
Salinity Hazard†	low	low	low	low	low	low	low	low	low-med	low	low	low
Sediment Yield (kg/ha)	1.6	6.1	20.0	7.7	2.2	7.7	10.1	7.0	4.5	5.7	7.9	10.0

	Paraho Retorted Shale		20 cm Soil/ Paraho		40 cm Soil/ Paraho		60 cm Soil/ Paraho		80 cm Soil/ Paraho		Soil Control	
	L1	L3	L5	L7	L9	L11	L13	L15	L17	L19	L21	L23
Runoff (cm)	-	8.5	8.2	8.6	8.7	9.2	9.5	9.1	10.0	8.7	8.5	9.0
EC (μmhos/cm)*	-	180	140	110	130	130	170	130	140	160	190	220
Salinity Hazard†	-	low	low	low	low	low	low	low	low	low	low	low
Sediment Yield (kg/ha)	-	3.2	8.9	26.1	11.8	37.2	22.1	13.8	40.4	6.0	23.2	51.5

* Values are in μmhos/cm @ 25°C

† Richards, L.A. (ed.). 1954.

\- No sample collected if less than 25 ℓ of runoff in primary collection container.

TABLE 9. WATER QUALITY ANALYSES OF SPRING SNOWMELT RUNOFF FROM THE HIGH-ELEVATION AND LOW-ELEVATION LYSIMETERS, NORTH-ASPECT, 2% SLOPE, MARCH 22, 1979.

	High-Elevation		Low-Elevation		
	20 cm Soil Paraho	40 cm Soil Paraho	Paraho Retorted Shale	80 cm Soil/ Paraho	
	H6	H10	L4	L18	L20
Runoff (cm)	0.22	0.17	0.16	0.12	0.26
pH	6.9	7.1	7.3	7.7	7.4
EC (μmhos/cm)	280	620	280	500	390
Na (meq/ℓ)	0.7	2.1	0.6	2.2	1.3
Ca (meq/ℓ)	0.9	1.0	0.6	1.0	1.0
Mg (meq/ℓ)	0.9	1.0	1.8	1.0	0.6
K (meq/ℓ)	0.2	0.5	0.2	0.7	0.3
CO_3 (meq/ℓ)	0	0	0	0	0
HCO_3 (meq/ℓ)	1.3	2.2	1.6	2.1	2.1
NO_3 (meq/ℓ)	0.3	0.02	0.06	0.15	0.03
SO_4 (meq/ℓ)	0.7	2.6	1.3	1.6	1.0
Cl (meq/ℓ)	0.5	1.8	0.5	1.5	1.0
SAR	0.7	2.1	0.6	2.2	1.4
Salinity Hazard	low	low-med	low	low	low
Sodium Hazard	low	low	low	low	low

TABLE 10. SPRING SNOWMELT RUNOFF AND WATER QUALITY ANALYSES FROM THE HIGH- AND LOW-ELEVATION LYSIMETERS, NORTH-ASPECT, 2% SLOPE, MARCH 20, 1980.

Treatment	HIGH ELEVATION											
	Paraho Spent Shale		20 cm Soil Cover Paraho		40 cm Soil Cover Paraho		60 cm Soil Cover Paraho		80 cm Soil Cover Paraho		Soil Control	
	H2	H4	H6	H8	H10	H12	H14	H16	H18	H20	H22	H24
Runoff (cm)	1.31	1.83	3.23	3.03	3.63	1.83	2.36	2.56	2.23	1.75	0.84	0.53
pH	7.2	7.2	7.2	7.0	6.9	7.1	7.1	7.1	7.1	6.9	7.0	7.1
EC (µmhos/cm)	170	170	70	60	60	100	60	50	70	60	80	100
Na (meq/l)	0.21	0.14	0.06	0.10	0.05	0.09	0.06	0.04	0.08	0.04	0.08	0.12
Ca (meq/l)	0.48	0.49	0.36	0.29	0.26	0.62	0.35	0.23	0.36	0.28	0.38	0.45
Mg (meq/l)	1.18	1.27	0.29	0.16	0.14	0.18	0.18	0.13	0.21	0.15	0.19	0.23
K (meq/l)	0.12	0.08	0.10	0.10	0.10	0.10	0.08	0.10	0.08	0.11	0.18	0.17
CO_3 (meq/l)	0	0	0	0	0	0	0	0	0	0	0	0
HCO_3 (meq/l)	1.6	1.5	0.6	0.5	0.4	0.7	0.4	0.4	0.6	0.5	0.5	0.06
SO_4 (meq/l)	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cl (meq/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
SAR	0.22	0.15	0.11	0.20	0.10	0.14	0.11	0.10	0.14	0.09	0.14	0.20
Salinity hazard	low	low	low	low	low	low	low	low	low	low	low	low
Sodium hazard	low	low	low	low	low	low	low	low	low	low	low	low

Treatment	LOW ELEVATION											
	Paraho Spent Shale		20 cm Soil Cover Paraho		40 cm Soil Cover Paraho		60 cm Soil Cover Paraho		80 cm Soil Cover Paraho		Soil Control	
	L2	L4	L6	L8	L10	L12	L14	L16	L18	L20	L22	L24
Runoff (cm)	0.11	0.69	0.73	0.84	0.77	0.03	1.02	0.73	1.02	1.87	0.77	0.22
pH	7.0	7.1	7.0	7.0	7.0	*	6.8	6.9	7.0	7.0	7.0	6.9
EC (µmhos/cm)	260	180	90	80	80	*	80	100	70	70	120	170
Na (meq/l)	0.36	0.19	0.05	0.05	0.05	*	0.05	0.06	0.04	0.06	0.14	0.38
Ca (meq/l)	0.46	0.39	0.51	0.51	0.51	*	0.37	0.46	0.37	0.36	0.52	0.59
Mg (meq/l)	1.60	1.24	0.31	0.26	0.25	*	0.27	0.30	0.21	0.23	0.38	0.48
K (meq/l)	0.51	0.18	0.12	0.08	0.11	*	0.15	0.13	0.13	0.13	0.21	0.24
CO_3 (meq/l)	0	0	0	0	0	*	0	0	0	0	0	0
HCO_3 (meq/l)	2.4	1.6	0.9	0.8	0.9	*	0.7	0.8	0.6	0.8	0.9	1.3
SO_4 (meq/l)	0.4	0.2	0.1	0.1	0.1	*	0.1	0.1	0.1	0.1	0.1	0.3
Cl (meq/l)	<0.1	<0.1	<0.1	<0.1	<0.1	*	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SAR	0.35	0.21	0.08	0.08	0.08	*	0.09	0.10	0.07	0.10	0.21	0.51
Salinity hazard	low	low	low	low	low	*	low	low	low	low	low	low
Sodium hazard	low	low	low	low	low	*	low	low	low	low	low	low

* inadequate sample size for analyses

All south aspects $\leq$ 0.02 cm runoff, no sample for analyses.

PERCOLATE

In 1977, after some treatments were leached, both high- and low-elevation lysimeter studies were irrigated to aid the establishment of vegetation. Only the high-elevation lysimeter study received additional irrigation in the early spring of 1978 and 1979. These differences were designed to study both the quantity and quality of the percolate resulting. In 1980, percolate from the high-elevation lsyimeters resulted from seasonal snowmelt alone, no supplemental irrigation was made. Continued leaching is planned for future studies.

Only data from the lower drains, below the compacted zone, are discussed, since 99% of the total volume of percolate was collected from these drains. Some percolate data were also calculated on a pore volume basis. One pore volume (including both the uncompacted and compacted zone) was calculated to be about 50,000 ℓ (110 cm) for a 6.7 x 6.7 m area with a depth of 2.4 m. The porosity of the uncompacted zone was approximately 49%, assuming a bulk density of 1.32 g/cm^3 and a particle density of 2.6 g/cm^3. The porosity of the compacted zone was approximately 41%, assuming an average bulk density of 1.53 g/cm^3 and a particle density similar to the uncompacted zone (Harbert et al., 1979). The volumes of percolate used in the following discussion are approximate, due to the probable interchange of soil solution between the 25% and 2%-slope, as no dividng wall separated the two slopes. Occasionally, the totalizing flow meter readings were incompatible with measured flow rates, in which case, the flow rates were used to estimate the volume of percolate. The following discussion addresses only some of the major hydrological observations. Another study was conducted separately (Chandler, 1979) which presented a more detailed interpretation and model of the hydrological data.

The Paraho retorted shale and the 20-cm soil/Paraho treatments of both high- and low-elevation lysimeters were continuously leached from June 2 through June 15, 1977. The total amount of water applied averaged between 76 and 78 centimeters. The EC of the Colorado River water used for leaching and establishment averaged 1 mmhos/cm. A sample of irrigation water was collected on June 3, 1977 for additional analysis (Harbert et al., 1979). Further irrigation for plant establishment, June 19 through August 17, 1977 resulted in application of approximately 84 cm of water to all treatments of the high-elevation lysimeter and 38 cm to all treatments of the low-elevation lysimeter.

Percolate collected from the lower drains of all treatments was analyzed for pH and EC. Total volume of percolate, EC, and pH are summarized in Table 11. The greatest volume of percolate resulted from those treatments which had been leached, and irrigated to establish vegetation (Paraho retorted shale and 20-cm soil/Paraho). The greatest EC values, ranging from 34 to 35 mmhos/cm, were generally associated with percolate produced by those treatment plots, as well as the high pH values (11.3 to 11.4). Overall there was some reduction of EC and pH as greater volumes of leachate moved through the lysimeters. The Paraho shale on the 25% slope of the high-elevation lysimeters produced the greatest volume of percolate and also measured the largest overall reduction of EC and pH; from 31.0 mmhos/cm (pH 11.3) to 11.4 mmhos/cm (pH 8.6) when approximately 0.7 pore volumes had passed through that lysimeter plot.

TABLE 11. PERCOLATE FROM THE LYSIMETER STUDY, 1977.

Treatment	Slope	Total Yearly Percolate	EC		pH	
			Max	Min	Max	Min
		- - - ℓ - - -	- mmhos/cm -			
HIGH ELEVATION						
Paraho Spent Shale	2%	9,513.8	34.5	11.2	11.5	10.9
	25%	34,110.4	31.0	11.4	11.3	8.3
20 cm Soil/Paraho	2%	2,179.0	35.1	14.6	11.4	10.6
	25%	24,636.6	28.4	14.4	11.4	9.4
40 cm Soil/Paraho	2%	447,4	22.3	19.8	11.2	9.9
	25%	3,860.7	24.5	17.4	10.6	9.6
60 cm Soil/Paraho	2%	0	0	0	0	0
	25%	1,308.9	22.9	19.4	8.4	8.1
80 cm Soil/Paraho	2%	0	0	0	0	0
	25%	1,771.8	22.3	14.4	10.8	10.5
Soil Control	2%	219.0	6.0	5.6	7.8	7.7
	25%	5,649.1	8.3	4.8	8.3	7.9
LOW ELEVATION						
Paraho Spent Shale	2%	1,042.6	29.3	18.1	11.2	8.3
	25%	706.8	34.1	8.1	10.9	7.2
20 cm Soil/Paraho	2%	771.4	28.1	14.4	11.2	9.0
	25%	4,638.5	24.9	14.9	11.3	7.7
40 cm Soil/Paraho	2%	0	0	0	0	0
	25%	0	0	0	0	0
60 cm Soil/Paraho	2%	0	0	0	0	0
	25%	0	0	0	0	0
80 cm Soil/Paraho	2%	0	0	0	0	0
	25%	0	0	0	0	0
Soil Control	2%	0	0	0	0	0
	25%	0	0	0	0	0

The volume of percolate produced from other treatments was considerably less (Table 11) making it difficult to interpret the limited chemical data obtained. A much greater pore volume leached through these treatments would be necessary to approach solution equilibria.

Approximately 20 cm of irrigation water was applied to the high-elevation lysimeters on April 10, 1978 in order to simulate the extra spring snowmelt of a high-elevation region. Additional applications of 3 cm each were also made on May 9 and June 27, 1978 to the same plots. The low-elevation lysimeters did not receive additional irrigations. This extra moisture resulted in the continued percolation of water through the high-elevation lysimeters. As before, the Paraho retorted shale and the 20-cm soil/Paraho treatments produced the greatest volume of leachate (Table 12). This was due to the residual moisture contained in these profiles from leach water of 1977. The maximum EC values of percolate from the treatments were reduced considerably over 1977 observations. The maximum EC for the Paraho retorted shale was 15.1 mmhos/cm, and 17.8 mmhos/cm for the 20-cm soil/Paraho. The pH of leachate from these treatments was also lower than 1977 values. Other treatments, because of less solution passing through the soil/shale matrix, continued to produce percolate with maximum EC values ranging from 13.7 to 31.7 mmhos/cm (Table 12). Leachate from the soil control remained low with respect to both EC and pH. The total volume of leachate from the 25% slope, Paraho retorted shale treatment for both 1977 and 1978 was calculated to be approximately 0.85 pore volume. None of the other treatments produced over 0.22 pore volume, except the 25% slope, 20-cm soil/Paraho which totaled approximately 0.67 pore volume. With the limited amounts of percolate obtained from most treatments, there were no definite trends observed concerning the chemical data collected. Most of the treatments continued to show fluctuations of EC and pH values of the leachate.

The high-elevation lysimeters received approximately 20 cm of supplemental irrigation on April 24, 1979. Two more irrigations of 3 cm each on May 21 and June 18, 1979 completed the simulation of spring snowmelt. Most treatments began to produce percolate in early April, even before the supplemental irrigation; peaked toward the end of April; and slowed to a minimal flow rate by the last irrigation application in June. Total volume of percolate was greatest for the 25% slope, Paraho retorted shale, reaching a cumulative total of 1.0 pore volume. The volume of percolate from the 2% slope remained considerably less than that from the 25% slope, probably due to the lack of a dividing wall between the treatments. Electrical conductivity and pH of leachate were similar to past observations with much variation between maximum and minimum values (Table 13). The treatments with greater amounts of leachate continued to show decreases in EC and pH over initial values. Those treatments through which only minimum amounts of leachate passed maintained higher EC values.

The high-elevation lysimeters did not receive additional irrigation in 1980. Limited percolate resulted only from three treatments (Table 14) with 25% slopes. The Paraho retorted shale produced the greatest volume of percolate. Electricaly conductivity values were higher than 1979 percolates, probably due to a concentrating effect of the smaller percolate volumes produced.

TABLE 12. PERCOLATE FROM THE LYSIMETER STUDY, 1978.

Treatment	Slope	Total Yearly Percolate	EC		pH	
			Max	Min	Max	Min
		- - - ℓ - - -	- mmhos/cm -			
HIGH ELEVATION						
Paraho Spent Shale	2%	4,149.1	13.2	8.2	10.8	8.2
	25%	8,527.6	15.1	7.2	8.7	7.2
20 cm Soil/Paraho	2%	462.5	16.1	7.8	9.4	8.1
	25%	8,658.2	17.8	11.0	9.1	7.4
40 cm Soil/Paraho	2%	1,092.7	31.7	16.1	9.1	8.2
	25%	5,969.0	25.5	10.0	9.2	7.4
60 cm Soil/Paraho	2%	107.1	13.7	11.3	8.2	7.5
	25%	2,879.6	20.9	7.1	8.6	7.7
80 cm Soil/Paraho	2%	946.3	15.9	10.6	9.0	7.6
	25%	4,087.0	21.5	9.9	8.9	7.6
Soil Control	2%	1,105.2	4.8	4.5	8.3	7.9
	25%	5,216.5	10.8	3.4	8.5	7.9
LOW ELEVATION						
Paraho Spent Shale	2%	5.0	15.5	10.7	8.0	7.9
	25%	0	0	0	0	0
20 cm Soil/Paraho	2%	20.0	15.2	0	8.2	0
	25%	180.0	17.4	16.4	8.4	8.1
40 cm Soil/Paraho	2%	0	0	0	0	0
	25%	0	0	0	0	0
60 cm Soil/Paraho	2%	0	0	0	0	0
	25%	0	0	0	0	0
80 cm Soil/Paraho	2%	0	0	0	0	0
	25%	0	0	0	0	0
Soil Control	2%	0	0	0	0	0
	25%	0	0	0	0	0

TABLE 13. PERCOLATE FROM THE LYSIMETER STUDY, 1979.

Treatment	Slope	Total Yearly Percolate	EC		pH	
			Max	Min	Max	Min
		- - - ℓ - - -	- mmhos/cm -			
HIGH ELEVATION						
Paraho Spent Shale	2%	903.1	11.6	7.4	9.1	7.7
	25%	7,171.8	16.6	6.2	9.1	7.7
20 cm Soil/Paraho	2%	223.7	11.7	7.3	9.3	7.3
	25%	5,969.3	15.4	10.1	9.4	7.8
40 cm Soil/Paraho	2%	817.6	16.2	14.4	9.8	9.7
	25%	5,059.0	29.7	20.5	9.2	8.4
60 cm Soil/Paraho	2%	0	0	0	0	0
	25%	2,487.9	22.3	9.3	9.1	7.9
80 cm Soil/Paraho	2%	199.1	21.0	11.2	8.9	7.3
	25%	3,384.2	31.6	21.9	8.8	8.4
Soil Control	2%	12.0	3.3	2.3	8.6	8.4
	25%	4.0	2.9	2.4	8.8	8.6
LOW ELEVATION						
Paraho Spent Shale	2%	15.0	13.0	8.8	8.3	8.1
	25%	0	0	0	0	0
20 cm Soil/Paraho	2%	5.0	12.6	0	8.3	0
	25%	60.0	20.0	0	8.0	0
40 cm Soil/Paraho	2%	0	0	0	0	0
	25%	0	0	0	0	0
60 cm Soil/Paraho	2%	0	0	0	0	0
	25%	0	0	0	0	0
80 cm Soil/Paraho	2%	0	0	0	0	0
	25%	0	0	0	0	0
Soil Control	2%	0	0	0	0	0
	25%	0	0	0	0	0

TABLE 14. PERCOLATE FROM THE LYSIMETER STUDY, 1980.

Treatment	Slope	Total Yearly Percolate	EC		pH	
			Max	Min	Max	Min
		- - - ℓ - - -	- mmhos/cm -			
HIGH ELEVATION						
Paraho Spent Shale	2%	0	0	0	0	0
	25%	318.7	23.9	10.5	8.7	8.3
20 cm Soil/Paraho	2%	0	0	0	0	0
	25%	91.2	16.4	12.0	8.7	8.3
40 cm Soil/Paraho	2%	0	0	0	0	0
	25%	22.7	35.3	30.1	9.9	8.9
60 cm Soil/Paraho	2%	0	0	0	0	0
	25%	0	0	0	0	0
80 cm Soil/Paraho	2%	0	0	0	0	0
	25%	0	0	0	0	0
Soil Control	2%	0	0	0	0	0
	25%	0	0	0	0	0
LOW ELEVATION						
Paraho Spent Shale	2%	0	0	0	0	0
	25%	0	0	0	0	0
20 cm Soil/Paraho	2%	0	0	0	0	0
	25%	0	0	0	0	0
40 cm Soil/Paraho	2%	0	0	0	0	0
	25%	0	0	0	0	0
60 cm Soil/Paraho	2%	0	0	0	0	0
	25%	0	0	0	0	0
80 cm Soil/Paraho	2%	0	0	0	0	0
	25%	0	0	0	0	0
Soil Control	2%	0	0	0	0	0
	25%	0	0	0	0	0

Total cumulative volumes for all treatments of both the high-elevation lysimeter and low-elevation lysimeter are shown in Table 15. Only the Paraho retorted shale on the 25% slope of the high-elevation lysimeter produced 1 pore volume of leachate. Percolate volumes from other treatments were generally limited. The objective of supplying additional irrigation water, on a yearly basis, to the high-elevation lysimeter was to evaluate the quantity and quality of percolate which might result from a processed oil shale disposal pile at an elevation where seasonal precipitation exceeded evapotranspiration, and resulted in percolate.

After the initial leaching and irrigation for plant establishment (which resulted in a minimal amount of percolate) no further irrigation was applied to the low-elevation lysimeters. On these treatments the vegetation was able to deplete the plant-available moisture in the profiles of most treatments, allowing a reservoir for spring recharge. Consequently, a significant amount of percolate did not result in later years.

Because of the limited percolate volume from most treatments, the EC values fluctuated considerably. The maximum EC was not always associated with the initial percolate from a particular lysimeter, nor were minimum EC values associated with the final percolate flowing from a lysimeter. Overall, however, a general drop in EC values was observed for treatments through which greater amounts of water had passed, such as the Paraho retorted shale, 25% slope, of the high-elevation lysimeter. In 1977, maximum EC values for leachate from this treatment were 31.0 mmhos/cm, dropped to 15.1 mmhos/cm by 1979, and returned to 23.9 mmhos/cm in 1980. Much greater volumes of water leached through the lysimeters would be required in order to stabilize the chemical composition of the percolate. Another, more extensive report involved modeling both chemical and hydrological aspects of the lysimeters (Chandler, 1979) and proposed continued leaching studies.

Laboratory analyses of the initial percolate collected in 1977 are reported in Table 16. Analyses for EC, pH, TDS, and common cations and anions were made in order to judge the quality of the percolate.

The EC measured in the laboratory was slightly lower than when determined in the field. This was most likely due to some salt precipitation before laboratory analyses were made. The pH values were considerably lower in the laboratory than those measured in the field. Skogerboe et al. (1978) attributed the drop in pH to oxidation of thiosulfates in the percolate.

The percolate collected from the lower drains of the lysimeters had a high soluble salt content from passing through 2.4 m of retorted shale. It can be predicted from these values that water moving through a retorted shale pile, several hundred meters thick, could be extremely saline.

Laboratory analyses also indicated that the sodium adsorption ratio (SAR) of the percolate was high. This suggested that the percolate could create soil dispersion problems in irrigated agriculture (Richards, 1954). The soil control produced percolate with a moderate SAR, increasing the possibility of a sodium dispersion problem in such soils if contaminated with retorted shale percolate.

TABLE 15. TOTAL PERCOLATE VOLUME FROM THE LYSIMETER STUDY, 1977-1980.

Treatment	Slope	1977	1978	1979	1980	Total
		- - -

TABLE 16. LABORATORY ANALYSES OF THE INITIAL PERCOLATE FROM THE HIGH-ELEVATION LYSIMETER, 1977.

	Percolate From Retorted Shale			Percolate From Soil		
	6/8/77	6/17/77	9/2/77	8/1/77	8/23/77	8/31/77
EC, µmhos/cm	12,983	27,222	10,500	4600	5100	5100
pH	6.3	7.1	7.0	7.5	8.2	8.3
TDS, ppm	14,328	31,984	*	*	*	*
SAR	52.8	116.8	30.0	10.8	9.7	9.7
Cations, meq/l						
Ca	16.4	23.0	17.4	8.8	6.9	5.4
Mg	9.0	5.1	1.5	8.5	21.4	19.8
Na	148.8	429.3	90.0	31.5	36.1	34.0
K	11.2	45.1	11.3	2.9	1.1	1.0
Anions, meq/l						
Cl	30.6	28.2	4.8	11.5	17.1	15.3
SO_4	157.7	449.6	119.0	35.6	37.5	36.2

* Not determined

CORE SAMPLE ANALYSES

Samples were taken September 1, 1977 of the uncompacted zone of the Paraho retorted shale treatments; the soil cover treatments were not sampled. Analyses of EC, pH, and common cations and anions were done (Table 17). In October 1979, core sampling of selected treatments was repeated, with only EC analyses made (Figure 13).

A comparison of the EC values for the Paraho retorted shale, before and after leaching, indicated a significant decrease in salinity. The original EC of 7.1 mmhos/cm dropped to approximately 3 to 4 mmhos/cm by the end of 1977. The 1979 core sample analyses indicated that the EC averaged 4 to 5 mmhos/cm to a depth of 160 cm of the Paraho retorted shale profile. Other treatments which had not been previously leached averaged EC values as high as 19.0 mmhos/cm at depths of 120 to 160 cm to the retorted shale (Figure 13). However, the latter values indicated that soluble salts moved downward under conditions of natural precipitation. There has been no indication of upward salt migration, into the soil cover of these treatments (Figure 13).

A considerable reduction in pH was observed between the time the retorted shale exited the retort (pH about 11.4) and sampling the material after leaching (average pH 9.1). The drop in pH was probably due to recarbonization from CO_2 in the atmosphere and leach water, and the displacement of alkaline anions by neutral salts from the irrigation water.

TABLE 17. ANALYSES OF PARAHO RETORTED SHALE BEFORE AND AFTER LEACHING AND PLANT ESTABLISHMENT, 1977.

Measurement	Before Leaching and Irrigation*	After Leaching And Irrigation †	
		High Elevation	Low Elevation
EC, mmhos/cm §	7.1	3.6	3.9
pH §	9.7	9.1	9.1
SAR §	19.0	2.5	3.0
Cations, meq/l §			
Ca	21.6	11.6	11.1
Mg	24.3	19.5	29.7
Na	91.5	11.3	13.1
K	7.1	1.6	1.8
Anions, meq/l §			
HCO_3	1.7	1.9	2.2
Cl	3.6	3.5	3.5
SO_4	131.3	33.5	45.0

* Mean value for four samples.

† Mean value for 23 to 45 core samples, all data are in Appendix Tables 107 and 108.

§ Analyses were on a 1:1 ratio of retorted shale to water by weight extract.

The sodium adsorption ratio (SAR) before leaching averaged 19.0 and decreased after leaching to around 3.0. This suggested that the irrigation water was effective in removing soluble sodium from the shale. As a result, SAR values as high as 123.1 were measured in the percolate from the Paraho retorted shale lysimeters (Harbert et al., 1979).

Analyses of samples after the 1977 irrigations indicated a relatively high proportion of magnesium to calcium (Harbert et al., 1979), which could result in nutrient imbalances, restricting plant growth on the Paraho retorted shale.

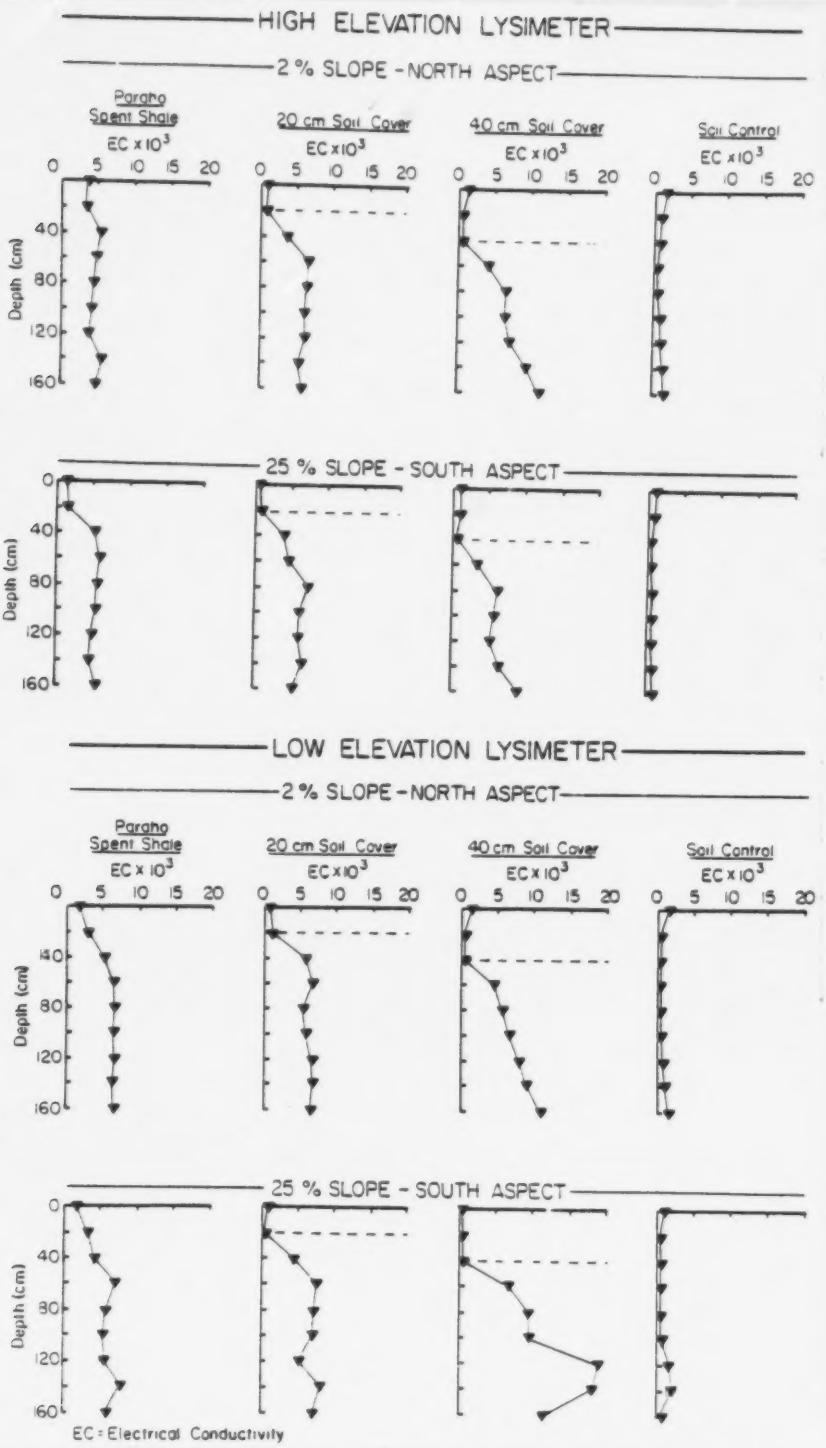


Figure 13. Soluble salt profiles of the lysimeter treatments, 1979.

WATER BALANCE

Water balance calculations were made for all treatments of both lysimeters for the 1977 season (Harbert et al., 1979). An attempt was made to account for the total volume of water applied to each treatment by estimating various inputs and losses. Inputs of moisture were fairly well defined and limited; such as precipitation and irrigation. Losses were more difficult to measure and estimate; such as percolation, moisture storage in the profile, and evapotranspiration.

For all of the leached treatments, amounts of water applied could not be accounted for by a summation of losses as they were measured or estimated. A water balance for the unleached treatments resulted in just the opposite in that water losses were calculated to be greater than water inputs. The moisture measurements for the soil control most nearly balanced inputs and losses. Other researchers have addressed the problem of water balances for the lysimeter study (Chandler, 1979).

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APPENDIX TABLES

APPENDIX TABLE 1. VEGETATIVE ANALYSIS (TRANSECT METHOD) OF THE HIGH-ELEVATION LYSIMETER, SOUTH-ASPECT, 25% SLOPE TREATMENTS, 1978.

	Paraho Spent Shale						20 cm Soil Cover/Paraho						40 cm Soil Cover/Paraho					
	H1			H3			H5			H7			H9			H11		
	line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3
PERENNIAL GRASSES																		
Western wheatgrass	44*	16	58	22	48	78	146	103	152	100	84	163	74	135	185	-	87	78
Bluebunch wheatgrass	13	-	-	-	4	-	73	60	130	66	69	46	-	95	44	234	56	15
Galleta	-	-	-	-	-	-	-	54	26	-	-	-	-	-	-	-	-	-
FORBS																		
Penstemon	-	-	-	-	-	-	-	3	-	-	30	8	-	27	12	4	19	4
Utah sweetvetch	-	-	-	5	-	-	-	-	-	-	10	-	-	-	27	-	13	-
Mint	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SHRUBS																		
Fourwing saltbush	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER SPECIES																		
Cheatgrass	-	-	-	-	-	-	-	-	-	30	23	-	-	-	-	-	16	-
Russian thistle	4	3	60	11	5	64	-	-	-	-	-	-	-	-	-	-	-	-
Kochia	72	28	30	83	103	23	-	-	-	-	-	-	-	-	-	-	-	-
Lambsquarter	15	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mustard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wheat	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	-	19	-
Wild barley	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25	-	-	-
Salt cedar	-	-	3	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-
Mallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gumweed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plantair	-	-	-	-	-	-	-	9	11	-	-	-	-	8	-	-	5	9
Alfalfa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NO VEGETATIVE COVER	69	273	156	229	190	154	47	77	-	79	82	45	22	58	25	58	65	8
LITTER	133	7	28	-	-	7	79	39	21	35	12	73	254	32	27	49	75	202

* Values are total cm of above ground vegetative cover by species. Transect lines averaged 350 cm in length, line 1 in upper, line 2 in middle, and line 3 in lower 1/3 of each plot.

APPENDIX TABLE 1. CONTINUED.

	60 cm Soil Cover/Paraho						80 cm Soil Cover/Paraho						Soil Control					
	H13			H15			H17			H19			H21			H23		
	line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3
PERENNIAL GRASSES																		
Western wheatgrass	95*	73	121	43	89	182	13	24	152	140	145	196	215	232	149	245	256	261
Bluebunch wheatgrass	88	47	7	54	-	92	-	-	32	12	33	65	-	-	31	21	27	40
Galleta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-
FORBS																		
Penstemon	25	-	-	22	-	9	-	-	-	-	13	4	-	10	-	9	23	-
Utah sweetvetch	-	-	4	-	-	6	-	-	-	-	-	-	-	-	-	-	9	-
Mint	-	-	-	-	-	-	-	-	-	-	-	-	40	-	-	-	-	-
SHRUBS																		
Fourwing saltbush	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER SPECIES																		
Cheatgrass	-	-	-	24	10	10	-	9	18	29	-	34	-	-	-	21	-	-
Russian thistle	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kochia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lambsquarter	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Mustard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wheat	-	9	-	-	-	-	-	-	10	12	-	-	-	-	25	-	-	-
Wild barley	-	-	-	-	-	-	-	-	-	-	-	-	11	20	-	-	-	19
Salt cedar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-	-
Mallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gumweed	-	-	8	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-
Plantain	-	-	-	-	7	-	56	36	-	-	-	-	-	-	84	-	-	-
Alfalfa	-	16	7	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-
													19	62	29	35	-	20
NO VEGETATIVE COVER	60	32	43	105	173	-	66	18	10	97	52	25	11	16	3	9	9	-
LITTER	72	163	150	96	63	47	185	238	114	73	122	26	44	-	-	5	-	-

* Values are total cm of above ground vegetative cover by species. Transect lines averaged 350 cm in length, line 1 in upper, line 2 in middle, and line 3 in lower 1/3 of each plot.

APPENDIX TABLE 2. VEGETATIVE ANALYSIS (TRANSECT METHOD) OF THE HIGH-ELEVATION LYSIMETER, NORTH-ASPECT, 2% SLOPE TREATMENTS, 1978.

	Paraho Spent Shale						20 cm Soil Cover/Paraho						40 cm Soil Cover/Paraho					
	H2			H4			H6			H8			H10			H12		
	line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3
PERENNIAL GRASSES																		
Western wheatgrass	56*	25	71	43	75	72	111	130	119	143	115	127	88	120	135	76	96	102
Bluebunch wheatgrass	-	-	8	-	14	16	42	88	67	17	94	123	39	79	103	118	105	104
Galleta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FORBS																		
Penstemon	-	-	-	-	-	-	-	9	-	-	8	6	-	-	-	9	-	-
Utah sweetvetch	-	-	-	-	-	-	-	-	2	-	-	9	-	-	-	-	-	-
Mint	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SHRUBS																		
Fourwing saltbush	14	16	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER SPECIES																		
Cheatgrass	35	-	-	-	-	-	-	-	29	-	-	-	-	18	-	37	-	-
Russian thistle	5	6	17	8	31	17	-	-	4	-	-	-	-	-	-	-	-	-
Kochia	40	100	58	135	46	45	-	-	-	-	-	-	-	-	-	-	-	-
Lambsquarter	34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mustard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wheat	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	3
Wild barley	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salt cedar	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-
Mallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gumweed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plantain	-	-	-	-	-	-	9	-	-	-	-	-	10	-	-	-	-	9
Alfalfa	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	9
NO VEGETATIVE COVER	91	92	79	77	66	88	19	36	7	39	15	27	13	35	37	18	18	9
LITTER	75	108	93	75	105	93	154	75	112	126	103	46	204	98	65	79	125	102

* Values are total cm of above ground vegetative cover by species. Transect lines averaged 350 cm in length, line 1 in upper, line 2 in middle, and line 3 in lower 1/3 of each plot.

APPENDIX TABLE 2. CONTINUED.

	60 cm Soil Cover/Paraho						30 cm Soil Cover/Paraho						Soil Control					
	H14			H16			H18			H20			H22			H24		
	line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3
PERENNIAL GRASSES																		
Western wheatgrass	92*	80	92	106	68	120	3	81	72	4	153	119	246	277	248	298	213	229
Bluebunch wheatgrass	40	7		128	87	130	-	40	107	-	93	158	16	15	70	18	49	65
Galleta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FORBS																		
Penstemon	-	-	-	-	-	4	-	-	-	-	9	9	-	-	4	-	-	-
Utah sweetvetch	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mint	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SHRUBS																		
Fourwing saltbush	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER SPECIES																		
Cheatgrass	-	-	-	26	41	-	-	-	24	-	43	-	17	-	-	-	11	-
Russian thistle	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kochia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lambsquarter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mustard	-	-	-	8	-	-	-	-	7	-	-	-	-	-	-	-	-	-
Wheat	-	-	-	-	13	-	-	-	-	-	12	-	28	25	-	15	38	24
Wild barley	-	-	-	-	-	-	-	22	-	-	17	-	-	-	-	-	-	-
Salt cedar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gumweed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plantain	5	31	4	-	6	-	31	22	11	77	-	-	8	5	-	-	-	-
Alfalfa	-	-	-	-	-	-	12	4	-	37	-	-	23	16	24	9	19	13
NO VEGETATIVE COVER	30	-	-	15	2	27	-	11	24	9	-	24	-	-	-	-	-	3
LITTER	173	212	240	58	123	57	269	145	90	238	33	43	7	-	-	-	-	-

* Values are total cm of above ground vegetative cover by species. Transect lines averaged 350 cm in length, line 1 in upper, line 2 in middle, and line 3 in lower1/3 of each plot.

APPENDIX TABLE 3. VEGETATIVE ANALYSIS (TRANSECT METHOD) OF THE LOW-ELEVATION LYSIMETER, SOUTH-ASPECT, 25% SLOPE, 1978.

	Paraho Spent Shale						20 cm Soil Cover/Paraho						40 cm Soil Cover/Paraho					
	L1			L3			L5			L7			L9			L11		
	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3
PERENNIAL GRASSES																		
Western wheatgrass	5*	8	7	-	7	-	4	3	11	7	-	17	11	14	-	12	54	36
Bluebunch wheatgrass	-	-	9	-	-	-	-	9	9	-	-	25	8	51	58	-	44	66
Galleta	-	-	-	-	-	-	47	93	99	31	35	109	26	53	9	92	101	115
Indian ricegrass	-	-	-	-	-	-	8	-	-	-	-	-	-	45	11	-	-	7
FORBS																		
Utah sweetvetch	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Penstemon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SHRUBS																		
Fourwing saltbush	84	-	11	4	-	-	5	13	23	-	-	-	-	-	42	-	2	5
Winterfat	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-
OTHER SPECIES																		
Cheatgrass	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	13	-	-
Russian thistle	84	3	33	40	4	81	-	-	-	-	-	-	-	-	-	-	33	13
Kochia	-	-	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-	-
Lambs quarter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mustard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wheat	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wild barley	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salt cedar	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plantain	-	-	-	-	-	-	12	36	15	-	10	-	56	48	39	-8	-	
Alfalfa	-	-	-	-	-	21	177	88	93	110	150	93	60	10	43	21	-	20
NO VEGETATIVE COVER	146	313	274	298	315	235	82	80	64	130	111	62	114	107	109	139	105	70
LITTER	-	-	-	-	-	-	15	11	18	47	24	29	58	5	24	52	-	9

* Values are total cm of above ground vegetative cover by species. Transect lines averaged 350 cm in length, line 1 in upper, line 2 in middle, and line 3 in lower 1/3 of each plot.

APPENDIX TABLE 3. CONTINUED.

	60 cm Soil Cover/Paraho						30 cm Soil Cover/Paraho						Soil Control					
	L13			L15			L17			L19			L21			L23		
	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3
PERENNIAL GRASSES																		
Western wheatgrass	16*	27	26	35	31	11	14	23	10	30	33	15	78	78	19	51	4	60
Bluebunch wheatgrass	32	35	16	27	62	3	3	45	39	8	19	-	19	60	82	42	34	41
Galleta	72	80	170	39	86	116	86	58	135	82	138	188	60	98	104	131	22	125
Indian ricegrass	-	18	10	-	20	-	-	-	10	-	-	-	38	5	10	39	30	8
FORBS																		
Utah sweetvetch	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Penstemon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SHRUBS																		
Fourwing saltbush	-	9	2	-	4	-	10	14	-	-	7	-	22	-	69	-	55	89
Winterfat	-	-	-	-	-	-	-	-	-	-	-	-	3	13	-	3	28	13
OTHER SPECIES																		
Cheatgrass	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-	-	-	-
Russian thistle	-	29	-	-	-	-	22	39	8	-	-	-	4	-	-	-	-	-
Kochia	-	-	-	-	-	-	-	-	-	-	-	-	-	44	-	-	-	-
Lambsquarter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mustard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wheat	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wild barley	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salt cedar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mallow	-	-	-	-	-	-	-	-	-	-	-	-	14	-	-	-	-	-
Plantain	-	-	-	-	-	12	49	14	-	28	-	-	-	-	-	-	-	-
Alfalfa	20	26	48	20	13	58	-	-	12	6	16	23	-	5	13	4	62	4
NO VEGETATIVE COVER	132	37	53	67	34	76	56	91	45	180	74	54	77	21	13	45	48	-
LITTER	63	77	13	138	66	59	91	54	78	41	72	62	15	12	28	20	44	8

* Values are total cm of above ground vegetative cover by species. Transect lines averaged 350 cm in length, line 1 in upper, line 2 in middle, and line 3 in lower 1/3 of each plot.

APPENDIX TABLE 4. VEGETATIVE ANALYSIS (TRANSECT METHOD) OF THE LOW-ELEVATION LYSIMETER, NORTH-ASPECT, 2% SLOPE, 1978.

	Paraho Spent Shale						20 cm Soil Cover/Paraho						40 cm Soil Cover/Paraho					
	L2			L4			L6			L8			L10			L12		
	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3
PERENNIAL GRASSES																		
Western wheatgrass	7*	5	27	37	11	40	22	25	14	15	32	76	17	18	91	40	43	27
Bluebunch wheatgrass	-	-	3	4	-	9	7	12	4	10	7	-	13	16	30	4	3	41
Galleta	-	-	8	4	-	-	86	107	118	86	97	115	80	82	94	98	110	50
Indian ricegrass	-	-	-	-	7	-	-	-	-	3	5	-	24	7	-	-	3	-
FORBS																		
Utah sweetvetch	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	4	-	-
Penstemon	-	-	-	-	-	-	-	-	-	-	-	-	-	3	7	-	-	-
SHRUBS																		
Fourwing saltbush	-	5	-	5	-	6	6	10	-	3	8	-	14	-	-	-	-	-
Winterfat	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER SPECIES																		
Cheatgrass	-	-	-	-	-	-	17	25	42	20	90	8	-	60	15	-	9	18
Russian thistle	12	-	3	10	3	15	-	-	-	-	-	-	-	-	-	-	-	-
Kochia	13	14	28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lambsquarter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mustard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15
Wheat	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16	9	-
Wild barley	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	6	-
Salt cedar	4	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-
Mallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plaintain	-	-	-	-	-	-	23	28	-	-	21	-	12	16	-	-	25	21
Alfalfa	-	-	-	-	4	-	84	-	36	26	22	21	23	43	7	-	-	63
NO VEGETATIVE COVER	279	303	268	279	310	265	81	118	54	123	45	72	116	83	74	147	100	102
LITTER	-	-	-	-	-	-	19	16	71	42	13	47	30	5	32	23	28	-

* Values are total cm of above ground vegetative cover by species. Transect lines averaged 350 cm in length, line 1 in upper, line 2 in middle, and line 3 in lower 1/3 of each plot.

APPENDIX TABLE 4. CONTINUED.

	60 cm Soil Cover/Paraho						80 cm Soil Cover/Paraho						Soil Control					
	L14			L16			L18			L20			L22			L24		
	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3	Line 1	Line 2	Line 3
PERENNIAL GRASSES																		
Western wheatgrass	46*	99	112	63	24	9	15	41	18	75	99	27	-	17	94	62	44	167
Bluebunch wheatgrass	34	41	38	17	9	2	74	60	20	36	57	143	-	17	19	57	23	37
Galleta	92	27	64	63	20	16	94	66	132	97	47	76	29	51	29	93	62	25
Indian ricegrass	-	6	-	-	-	-	3	12	-	23	7	-	20	-	-	-	-	4
FORBS																		
Utah sweetvetch	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	5
Penstemon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SHRUBS																		
Fourwing saltbush	14	-	-	22	4	2	-	38	-	-	12	11	11	5	4	25	7	-
Winterfat	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	24	-	4
OTHER SPECIES																		
Cheatgrass	-	-	-	9	210	151	-	-	9	7	-	-	85	10	25	-	-	-
Russian thistle	-	-	-	-	-	-	-	6	4	6	47	-	-	-	-	8	-	30
Kochia	-	-	8	17	-	-	-	-	-	-	8	-	6	16	-	-	-	-
Lambsquarter	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-
Mustard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wheat	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wild barley	-	9	-	-	-	-	-	-	21	-	-	-	-	-	-	-	-	-
Salt cedar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plantain	8	5	10	15	-	26	9	-	-	-	-	-	31	60	18	-	-	-
Alfalfa	-	10	-	29	5	67	6	10	10	-	6	5	104	94	118	20	13	34
NO VEGETATIVE COVER	98	105	84	71	34	27	113	93	60	69	61	69	30	20	17	46	106	33
LITTER	38	30	10	27	28	25	14	9	59	45	-	12	23	47	13	-	12	8

* Values are total cm of above ground vegetative cover by species. Transect lines averaged 350 cm in length, line 1 in upper, line 2 in middle, and line 3 in lower 1/3 of each plot.

APPENDIX TABLE 5. MOISTURE MEASUREMENTS (NEUTRON PROBE) FROM THE HIGH-ELEVATION LYSIMETER, SOUTH-ASPECT, 25% SLOPE TREATMENTS, 1978.

Paraho Spent Shale

Depth (cm)	H1								H3							
	4/7	* 5/9 *	5/23	6/7	6/20 *	7/3	8/2	9/7	4/7	* 5/9 *	5/23	6/7	6/30 *	7/3	8/2	9/7
15	20.0	21.6	10.2	16.2	11.0	11.1	4.3	3.3	24.0	24.1	23.1	20.5	15.2	14.7	7.6	6.1
30	21.5	21.0	20.1	18.0	16.0	14.2	7.1	5.6	25.0	23.4	23.0	19.8	17.3	16.0	13.2	11.1
45	19.0	19.2	18.2	17.3	16.0	14.7	8.6	7.6	20.0	19.2	18.5	18.0	16.7	13.7	14.3	12.7
60	19.0	18.0	17.6	17.3	14.9	14.2	11.1	9.5	17.0	16.0	16.7	15.5	14.2	12.6	12.7	12.1
75	18.0	16.9	17.0	16.7	14.4	14.7	13.7	12.5	16.5	15.7	17.3	15.5	13.2	13.2	12.7	12.1
90	21.0	19.2	18.9	19.2	16.5	16.0	17.0	15.6	19.0	18.0	17.3	17.3	14.7	15.2	14.3	13.7
105	28.5	27.6	24.0	22.4	20.9	20.6	19.0	19.0	20.5	19.2	19.2	19.2	16.3	15.2	16.4	15.9
120	--	--	26.3	25.7	23.2	--	22.1	22.4	24.5	21.6	21.0	19.9	19.0	16.3	18.0	17.5
135	--	--	--	--	--	--	--	--	--	--	--	--	--	17.8	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

20 cm Soil Cover/Paraho

Depth (cm)	H5								H7							
	4/7	* 5/9 *	5/23	6/7	6/20 *	7/3	8/2	9/7	4/7	* 5/9 *	5/23	6/7	6/20 *	7/3	8/2	9/7
15	19.0	18.0	13.1	10.4	12.4	9.3	7.6	6.6	24.0	21.6	17.6	14.0	10.0	10.0	9.9	8.6
30	21.0	20.4	17.9	12.0	11.8	11.0	10.6	10.6	25.5	21.6	20.1	15.0	11.0	11.5	10.9	10.3
45	22.5	22.5	21.8	14.1	13.3	13.8	12.1	11.6	23.5	22.2	20.8	16.4	14.0	14.0	13.6	12.3
60	22.0	22.2	21.1	17.5	14.9	14.9	13.7	13.7	23.5	20.8	20.1	18.9	14.5	15.5	15.2	14.4
75	13.0	14.1	13.1	12.0	11.8	11.3	12.1	10.6	20.0	18.0	17.6	17.6	14.5	14.0	14.1	13.3
90	10.0	9.3	10.2	9.3	8.0	9.3	9.1	8.6	23.0	19.2	18.9	17.0	15.0	15.0	15.0	13.8
105	10.0	11.4	10.8	9.3	8.0	9.3	9.1	9.1	23.5	19.8	21.4	17.6	16.0	16.5	16.3	15.4
120	--	18.0	17.9	14.7	16.5	16.0	15.9	15.3	23.0	19.8	20.0	20.1	17.1	16.5	17.5	16.0
135	--	--	16.7	--	--	--	--	--	--	--	22.1	--	17.6	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

40 cm Soil Cover/Paraho

Depth (cm)	H9								H11							
	4/7	* 5/9 *	5/23	6/7	6/20 *	7/3	8/2	9/7	4/7	* 5/9 *	5/23	6/7	6/20 *	7/3	8/2	9/7
15	16.0	19.8	13.2	9.6	8.5	10.7	7.6	6.5	25.0	22.2	15.7	11.6	9.8	11.5	8.6	8.3
30	23.0	21.6	18.0	12.3	10.8	11.1	10.0	9.9	25.0	21.6	17.0	12.7	10.8	11.0	10.0	9.8
45	25.0	24.1	22.4	15.6	13.8	12.1	11.6	11.5	23.5	20.4	17.5	12.7	11.3	11.0	10.0	9.8
60	27.0	25.3	24.3	19.2	14.8	15.2	14.3	14.0	15.5	18.0	17.5	13.2	11.3	11.5	11.1	10.9
75	23.0	22.9	22.4	18.0	15.3	15.7	14.8	14.0	15.5	16.9	17.0	14.3	12.3	12.5	12.7	11.9
90	20.5	19.8	19.8	17.4	15.8	15.7	15.3	14.6	15.5	15.7	17.0	14.3	13.3	12.0	12.7	12.3
105	22.0	21.0	21.1	18.0	16.8	16.3	16.4	16.7	16.5	18.0	18.9	16.5	16.0	15.5	14.8	14.9
120	19.5	19.8	18.5	17.4	15.8	15.7	15.3	15.1	--	20.4	20.0	17.7	17.5	16.5	16.4	16.0
135	--	--	16.2	--	14.3	--	--	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

* Values are in percent moisture by volume as determined from a standard soil moisture curve.

\+ Indicates the application of additional sprinkler irrigations - 4/10/78 - average of 8 inches applied to simulate spring snowmelt.
5/09/78 - average of 1.2 inches applied
6/27/78 - average of 1.2 inches applied

APPENDIX TABLE 5. CONTINUED.

Depth (cm)	60 cm Soil Cover/Paraho															
	H13								H15							
	4/7	4/10 †	5/9 †	5/23	6/7	6/20 †	7/3	8/2	9/7	4/7	4/10 †	5/9 †	5/23	6/7	6/20 †	7/3	8/2	9/7
15	22.5*	16.0	14.3	9.0	8.3	11.5	8.1	7.6	22.5	16.3	15.1	11.9	9.8	10.8	8.6	8.5		
30	25.0	20.4	16.7	11.6	10.7	11.5	11.6	10.6	24.5	18.9	17.5	14.2	11.7	11.3	11.6	10.5		
45	25.0	21.0	16.7	12.5	11.2	11.0	11.6	10.6	24.5	21.0	19.5	14.0	11.7	11.3	11.1	10.5		
60	22.5	20.4	16.1	12.0	11.2	11.0	11.1	11.1	25.0	23.6	23.5	17.6	12.1	13.3	12.1	12.0		
75	23.0	21.0	17.9	13.6	11.7	13.5	11.1	11.1	26.0	24.8	23.5	18.9	16.6	15.4	15.9	15.6		
90	21.5	20.4	19.2	16.3	14.1	15.0	14.3	13.2	23.5	20.6	22.8	19.5	16.6	16.5	17.0	15.6		
105	22.5	21.6	19.8	17.5	15.6	16.0	17.0	16.4	23.5	19.5	20.0	19.5	16.1	16.5	16.4	15.6		
120	21.5	21.6	19.8	18.0	17.1	17.6	17.0	17.0	19.0	18.4	20.1	18.3	16.1	17.0	15.9	16.2		
135	--	21.6	20.5	18.0	16.6	17.1	17.5	17.5	19.0	19.5	20.1	18.3	16.1	16.5	15.9	16.2		
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--		

Depth (cm)	91 cm Soil Cover/Paraho															
	H17								H19							
	4/7	4/10 †	5/9 †	5/23	6/7	6/20 †	7/3	8/2	9/7	4/7	4/10 †	5/9 †	5/23	6/7	6/20 †	7/3	8/2	9/7
15	22.5	19.2	20.5	13.2	10.8	13.3	9.2	9.1	19.0	20.1	13.2	9.7	8.1	9.5	7.0	6.9		
30	24.0	19.2	21.9	15.4	12.3	12.8	11.0	11.6	25.0	21.2	16.7	13.6	--	11.5	10.5	10.5		
45	25.0	22.2	24.6	16.6	12.8	13.3	13.4	12.7	25.0	21.9	16.7	14.2	--	11.0	11.5	10.5		
60	25.0	22.8	25.3	17.7	13.8	13.8	13.4	12.7	25.0	22.5	16.7	14.2	11.0	11.5	11.5	12.0		
75	25.0	24.0	25.3	19.5	15.3	15.4	14.5	15.3	25.5	23.7	19.2	17.1	12.8	13.0	12.0	12.5		
90	25.0	23.4	25.3	20.8	17.3	18.1	16.6	16.4	26.0	25.6	23.0	22.0	16.7	17.2	16.2	15.6		
105	24.0	22.8	24.6	20.1	18.4	18.1	17.0	17.0	22.0	22.5	20.5	19.5	16.2	18.1	16.2	15.6		
120	22.5	20.4	23.9	20.7	17.9	18.1	17.0	17.0	18.5	20.1	18.6	17.6	15.2	16.0	14.61	14.6		
135	--	--	21.1	18.3	16.0	--	16.1	--	21.5	21.2	19.8	20.1	16.2	17.6	15.6	16.7		
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--		

Depth (cm)	Soil Control															
	H21								H23							
	4/7	4/10 †	5/9 †	5/23	6/7	6/20 †	7/3	8/2	9/7	4/7	4/10 †	5/9 †	5/23	6/7	6/20 †	7/3	8/2	9/7
15	16.5	16.3	11.1	7.9	7.1	7.3	6.0	5.5	18.0	17.5	12.5	9.3	7.8	7.8	7.1	6.0		
30	25.0	20.4	17.2	12.7	11.3	11.1	10.9	10.1	26.5	19.8	17.9	12.0	11.1	11.1	10.6	10.3		
45	27.5	23.4	19.2	13.2	12.3	11.6	12.0	11.1	33.0	17.1	23.8	15.8	12.6	12.1	11.6	11.3		
60	28.5	26.6	23.2	15.4	--	13.7	12.5	11.6	31.5	27.7	28.0	17.5	13.2	12.6	12.7	11.8		
75	28.0	27.9	25.3	17.7	15.3	13.7	13.0	12.1	30.5	27.7	29.4	19.2	13.7	12.6	12.1	11.8		
90	28.0	27.9	25.3	18.9	14.8	14.2	12.5	11.6	33.0	29.0	29.4	22.8	14.7	12.6	11.1	10.8		
105	28.0	27.3	28.2	22.6	16.8	11.1	16.1	13.2	30.0	29.0	30.2	25.3	17.3	13.2	11.1	11.3		
120	28.0	28.6	29.7	25.1	19.5	18.4	15.6	13.7	26.5	27.1	25.9	22.8	17.8	15.2	11.1	10.3		
135	28.0	30.6	29.7	25.8	21.7	19.0	15.6	13.2	--	--	--	--	--	--	--	--		
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--		

* Values are in percent moisture by volume as determined from a standard soil moisture curve.

† Indicates the application of additional sprinkler irrigations - 4/10/70 - average of 8 inches applied to simulate spring snowmelt
5/09/70 - average of 1.2 inches applied
6/27/70 - average of 1.2 inches applied

APPENDIX TABLE 6. MOISTURE MEASUREMENTS (NEUTRON PROBE) FROM THE HIGH-ELEVATION LYSIMETER, NORTH-ASPECT, 2% SLOPE TREATMENTS, 1978.

Depth (cm)	Paraho Spent Shale															
	H2								H4							
	4/7 †	5/9 †	5/23	6/7	6/20 †	7/3	8/2	9/7	4/7 †	5/9 †	5/23	6/7	6/20 †	7/3	8/2	9/7
15	17.5*	13.0	11.7	8.2	6.3	7.8	3.2	2.9	10.5	20.4	17.6	12.8	11.8	14.5	8.6	7.1
30	18.0	20.6	19.5	17.2	15.2	15.4	9.3	9.1	8.0	15.7	14.6	11.8	12.3	12.0	10.6	9.6
45	20.0	21.7	18.2	15.5	14.7	14.9	12.3	11.1	10.0	11.4	10.0	8.3	9.0	8.6	8.6	7.6
60	22.5	17.3	17.6	16.1	15.2	14.9	13.8	13.4	13.5	8.3	8.3	7.0	7.1	7.2	7.1	6.6
75	23.5	21.8	22.1	18.9	18.4	18.1	17.5	17.2	17.5	10.4	9.5	7.8	8.5	8.1	8.6	8.1
90	22.5	23.6	23.4	20.7	20.0	19.8	19.8	18.9	--	14.6	14.0	11.4	12.3	12.5	12.1	12.7
105	21.0	23.0	24.0	22.5	21.2	20.9	20.4	20.1	--	19.2	18.9	15.5	16.8	14.5	17.0	15.9
120	--	22.4	23.4	21.9	20.6	19.8	19.2	18.9	--	--	--	--	--	--	--	--
135	--	22.4	22.7	21.9	20.6	19.8	18.6	17.8	--	--	--	--	--	--	--	--
150	--	--	22.7	21.2	20.0	--	18.6	18.9	--	--	--	--	--	--	--	--

Depth (cm)	20 cm Soil Cover/Paraho															
	H6								H8							
	4/7 †	5/9 †	5/23	6/7	6/20 †	7/3	8/2	9/7	4/7 †	5/9 †	5/23	6/7	6/20 †	7/3	8/2	9/7
15	20.5	19.5	11.9	9.3	6.9	11.6	6.9	6.1	18.0	19.2	11.4	8.2	8.7	10.8	6.8	6.5
30	16.5	20.6	18.9	15.8	11.3	14.2	12.1	11.1	21.0	20.4	15.9	11.6	10.1	11.3	8.7	8.5
45	15.0	20.6	19.5	16.9	14.9	14.7	14.3	13.2	20.0	19.2	18.3	13.7	11.1	11.8	10.1	10.5
60	13.5	16.2	16.5	15.2	13.8	13.7	13.8	12.1	15.0	16.3	14.8	11.6	11.1	11.3	10.1	10.5
75	14.0	14.6	15.3	12.5	12.3	12.6	12.7	12.1	11.0	20.0	11.4	9.7	9.7	9.8	8.7	9.0
90	--	13.5	14.2	12.0	11.8	11.6	11.6	10.6	10.0	11.4	10.8	9.7	9.2	9.3	9.2	9.0
105	--	13.5	14.2	13.0	12.3	11.6	12.1	11.6	17.0	19.2	17.1	14.7	14.2	15.4	14.2	14.6
120	--	--	--	--	--	--	--	--	--	--	26.6	22.9	23.5	--	22.9	--
135	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	40 cm Soil Cover/Paraho															
	H10								H12							
	4/7 †	5/9 †	5/23	6/7	6/20 †	7/3	8/2	9/7	4/7 †	5/9 †	5/23	6/7	6/20 †	7/3	8/2	9/7
15	19.5	19.8	13.9	9.3	7.8	9.5	6.9	7.2	19.0	20.4	13.5	10.4	8.2	10.7	7.5	6.9
30	24.0	22.1	14.5	12.5	10.8	10.5	10.3	10.7	21.0	20.4	14.6	12.5	10.5	10.7	9.9	9.3
45	20.0	18.6	14.5	13.0	10.3	11.0	9.8	9.7	22.0	24.7	19.5	13.6	12.0	11.1	10.5	10.3
60	20.0	19.8	18.9	15.8	12.9	12.5	11.3	11.8	28.5	24.7	22.7	15.8	13.5	14.2	12.5	12.8
75	21.5	22.1	22.1	13.0	16.0	16.5	16.0	15.5	26.5	21.0	19.5	15.8	14.0	15.2	13.5	13.3
90	24.0	23.3	24.2	21.0	19.2	19.2	17.5	18.3	16.5	18.6	18.2	14.7	14.0	13.7	13.0	12.3
105	27.5	24.5	24.9	22.2	20.9	20.9	20.4	20.1	18.0	19.2	18.2	18.0	15.5	15.7	15.6	14.4
120	--	--	--	--	--	--	--	--	22.0	24.7	23.4	20.4	18.7	11.5	18.4	17.5
135	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

* Values are in percent moisture by volume as determined from a standard soil moisture curve.

† Indicates the application of additional sprinkler irrigations - 4/10/78 - average of 8 inches applied to simulate spring snowmelt.
5/09/78 - average of 1.2 inches applied
6/27/78 - average of 1.2 inches applied

APPENDIX TABLE 6. CONTINUED.

60 cm Soil Cover/Paraho

Depth (cm)	H14								H16							
	4/7 +	5/9 +	5/23	6/7	6/20 +	7/3	8/2	9/7	4/7 +	5/9 +	5/23	6/7	6/20 +	7/3	8/2	9/7
15	23.0*	20.1	15.5	9.0	8.2	15.0	7.5	6.4	20.5	20.4	13.9	9.2	7.8	11.1	6.9	6.2
30	24.0	18.9	16.2	12.0	10.7	14.0	9.9	9.3	24.5	22.8	18.9	12.3	11.1	12.1	9.3	9.7
45	24.0	18.9	16.7	12.0	10.7	11.5	10.5	9.8	31.0	22.8	21.5	13.4	11.1	11.6	10.3	10.2
60	22.0	18.3	17.3	12.0	10.7	10.5	10.5	10.8	27.0	22.2	20.8	13.4	11.1	10.7	9.8	10.2
75	19.5	17.7	17.3	13.0	11.6	12.0	12.0	11.3	19.5	20.5	20.1	13.9	11.6	11.6	10.8	10.7
90	17.0	16.1	15.5	13.0	12.1	12.0	12.5	11.3	14.0	12.6	13.9	11.3	11.1	10.1	9.8	10.2
105	16.0	16.1	15.5	13.0	12.6	12.5	17.3	12.3	13.5	12.5	12.7	11.3	10.1	10.1	9.8	9.7
120	20.5	20.1	20.5	17.3	16.3	12.5	--	16.0	15.0	15.7	16.3	13.4	12.6	12.6	12.3	12.8
135	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

80 cm Soil Cover/Paraho

Depth (cm)	H18								H20							
	4/7 +	5/9 +	5/23	6/7	6/20 +	7/3	8/2	9/7	4/7 +	5/9 +	5/23	6/7	6/20 +	7/3	8/2	9/7
15	15.5	15.3	10.6	6.0	5.5	8.8	5.0	4.4	8.0	8.1	4.8	2.9	2.3	3.1	2.3	2.0
30	23.5	19.8	17.0	12.0	11.6	12.8	9.8	10.4	21.0	19.8	14.8	10.4	9.3	10.5	8.8	7.7
45	25.0	20.9	17.0	12.5	11.1	12.8	10.8	10.9	23.5	20.9	17.3	12.5	12.3	11.0	10.5	9.2
60	25.5	22.1	18.2	13.5	12.1	12.3	10.8	11.4	23.5	21.5	19.8	14.7	11.8	11.5	10.9	10.2
75	24.5	22.1	19.5	14.6	12.11	13.3	11.8	12.0	23.5	21.5	19.8	13.6	11.8	11.0	9.9	10.7
90	23.0	21.5	19.5	15.6	14.2	14.9	13.3	14.7	21.0	20.9	20.5	13.6	11.8	12.0	10.5	10.2
105	19.5	17.5	17.6	15.6	14.2	14.9	13.8	14.1	24.0	22.8	22.4	18.0	16.5	16.5	15.1	16.1
120	19.5	18.6	18.9	16.2	15.7	15.4	15.4	15.2	19.0	19.2	19.8	18.0	16.5	--	15.6	14.5
135	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Soil Control

Depth (cm)	H22								H24							
	4/7 +	5/9 +	5/23	6/7	6/20 +	7/3	8/2	9/7	4/7 +	5/9 +	5/23	6/7	6/20 +	7/3	8/2	9/7
15	13.5	13.6	7.3	5.8	4.4	5.5	4.1	3.3	15.0	14.6	9.1	5.8	4.0	5.7	4.3	3.4
30	21.0	19.8	14.0	12.3	10.4	12.8	9.8	9.9	23.5	20.4	17.3	11.4	9.5	8.8	8.1	8.2
45	23.0	23.4	17.0	13.9	11.8	13.3	11.3	11.5	26.0	22.2	19.2	12.5	10.5	9.8	9.6	9.7
60	22.0	24.0	18.9	14.5	12.3	12.8	11.3	11.5	34.5	26.0	23.1	13.7	11.0	11.7	10.6	10.2
75	23.0	26.6	23.4	17.8	12.3	12.3	11.8	11.5	34.5	26.6	25.2	18.6	14.0	11.7	11.6	11.3
90	23.0	26.6	24.7	18.3	15.3	14.9	12.3	12 0	33.5	29.9	26.6	21.5	15.0	13.6	12.1	11.8
105	28.0	26.6	26.1	21.2	17.3	16.0	13.3	12.0	33.5	27.3	27.3	21.5	17.1	14.1	12.1	11.8
120	28.0	26.6	26.1	21.9	18.4	17.5	13.8	12.5	32.0	27.9	28.0	23.3	19.2	16.1	13.2	11.8
135	28.0	29.3	27.5	24.0	19.0	18.6	14.4	12.0	36.0	--	30.2	25.2	22.0	19.2	13.7	12.8
150	29.5	30.0	28.9	26.6	21.7	21.5	16.0	13.5	--	--	--	--	--	--	--	--

* Values are in percent moisture by volume as determined from a standard soil moisture curve.

\+ Indicates the application of additional sprinkler irrigations - 4/10/78 - average of 8 inches applied to simulate spring snowmelt
5/09/78 - average of 1.2 inches applied
6/27/78 - average of 1.2 inches applied.

APPENDIX TABLE 7. MOISTURE MEASUREMENTS (NEUTRON PROBE) FROM THE LOW-ELEVATION LYSIMETER, SOUTH-ASPECT, 25% SLOPE TREATMENTS, 1978.

Depth (cm)	Paraho Spent Shale											
	L1						L3					
	4/7	5/9	6/9	7/7	8/2	9/8	4/7	5/9	6/9	7/7	8/2	9/8
15	10.0*	10.5	5.1	3.2	1.9	1.9	21.5	18.9	13.8	11.3	7.7	6.4
30	15.0	14.9	11.3	6.2	4.7	4.2	23.5	20.1	16.5	16.0	13.9	12.3
45	15.5	16.0	13.3	9.2	6.6	6.0	26.0	21.2	18.1	17.0	15.5	13.8
60	18.5	18.3	15.4	13.8	10.0	8.0	27.0	21.2	18.6	18.1	16.6	16.0
75	18.5	19.5	17.0	15.7	13.7	11.5	27.5	21.2	18.6	18.1	17.8	16.5
90	21.0	19.5	17.5	17.3	16.4	14.6	27.0	20.6	18.1	18.1	17.2	16.5
105	20.5	19.5	17.0	16.8	15.8	15.6	26.0	21.2	19.2	19.2	18.0	17.5
120	19.5	19.5	17.0	17.3	16.4	15.1	26.0	20.6	19.2	18.6	18.9	17.5
135	--	--	--	--	--	--	--	--	18.6	19.8	18.3	17.5
150	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	20 cm Soil Cover/Paraho											
	L5						L7					
	4/7	5/9	6/9	7/7	8/2	9/8	4/7	5/9	6/9	7/7	8/2	9/8
15	14.5	11.9	1.4	1.9	1.1	1.0	19.0	11.4	6.9	7.0	6.6	6.2
30	22.5	14.7	6.9	7.5	6.8	6.6	24.0	14.7	11.3	10.9	10.8	9.7
45	26.0	17.5	10.3	10.5	9.8	9.6	27.5	19.2	15.4	13.5	13.7	13.4
60	24.5	13.6	12.8	12.5	12.0	11.6	28.5	20.4	17.5	16.2	14.8	15.0
75	17.0	10.9	12.3	10.5	10.9	10.6	26.5	19.2	16.0	15.6	14.8	15.0
90	15.0	11.4	10.3	10.5	9.8	9.6	25.5	19.8	17.5	16.7	16.4	16.6
105	13.5	14.1	11.3	10.5	11.4	11.1	27.5	19.8	19.2	19.0	17.0	17.2
120	17.0	14.7	13.3	13.0	13.6	12.7	27.5	20.4	19.8	19.0	18.0	17.8
135	--	--	14.4	14.6	14.1	13.2	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	40 cm Soil Cover/Paraho											
	L9						L11					
	4/7	5/9	6/9	7/7	8/2	9/8	4/7	5/9	6/9	7/7	8/2	9/8
15	13.5	11.0	5.0	4.1	4.3	3.3	17.0	13.6	6.9	5.5	4.8	4.2
30	25.5	15.4	9.3	8.8	7.7	8.1	21.5	18.0	9.8	7.3	7.8	8.0
45	25.5	17.7	9.8	8.8	8.7	8.6	21.0	19.8	10.3	8.7	7.8	7.5
60	25.5	18.9	11.8	11.3	10.7	11.6	21.0	19.2	13.3	10.1	10.4	9.5
75	23.5	18.3	14.9	13.8	13.4	13.7	19.0	19.2	14.6	12.1	12.5	10.9
90	24.5	18.3	16.0	14.9	15.5	14.8	11.5	14.7	13.8	11.6	12.0	10.9
105	22.0	17.7	15.4	15.4	15.0	14.8	5.0	8.3	7.8	7.8	8.3	8.0
120	20.0	18.9	15.4	15.4	15.0	14.8	3.5	3.4	3.7	4.5	4.8	4.7
150	--	17.1	15.4	15.4	15.5	15.9	3.5	3.9	3.7	3.7	4.4	4.2

* Values are in percent moisture by volume as determined from a standard soil moisture curve.

† Indicates the application of additional sprinkler irrigations - 4/10/78 - average of 8 inches applied to simulate spring snowmelt
5/09/78 - average of 1.2 inches applied
6/27/78 - average of 1.2 inches applied

APPENDIX TABLE 7. CONTINUED.

60 cm Soil Cover/Paraho

Depth (cm)	L13						L15					
	4/7	5/9	6/9	7/7	8/2	9/8	4/7	5/9	6/9	7/7	8/2	9/8
15	24.0*	11.4	7.3	6.0	5.7	6.0	21.5	12.7	10.3	6.7	5.7	5.1
30	27.0	15.2	10.1	9.5	9.1	7.8	24.5	15.4	10.8	9.5	9.1	8.5
45	27.5	16.9	10.6	9.9	9.6	8.8	23.0	14.9	10.8	9.5	9.6	9.0
60	25.5	17.5	11.6	10.5	10.0	9.3	24.0	16.0	11.8	9.5	9.6	9.0
75	20.5	15.2	11.1	10.5	9.1	8.8	22.0	17.1	12.7	11.0	11.1	10.5
90	13.5	11.6	9.6	9.5	9.1	7.8	16.5	17.1	9.8	11.5	11.1	11.5
105	6.0	9.3	8.2	9.5	8.1	6.9	9.5	9.0	--	9.1	9.1	9.0
120	4.0	17.0	5.5	8.0	5.2	5.0	--	--	--	--	--	--
135	--	--	--	9.9	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--

80 cm Soil Cover/Paraho

Depth (cm)	L17						L19					
	4/7	5/9	6/9	7/7	8/2	9/8	4/7	5/9	6/9	7/7	8/2	9/8
15	20.5	17.1	6.7	6.0	5.3	4.7	21.0	14.1	6.3	4.9	3.8	3.8
30	27.0	18.9	10.0	9.3	9.2	8.0	26.0	16.3	10.0	8.2	8.5	7.6
45	26.0	20.1	10.0	9.3	9.2	9.0	24.0	16.3	10.0	8.6	8.5	8.1
60	25.5	20.1	9.1	10.3	9.7	9.5	23.0	16.9	10.0	8.6	7.5	8.6
75	25.0	21.3	14.0	11.3	10.7	9.5	19.0	16.3	9.1	7.7	7.5	7.6
90	20.5	18.9	14.0	13.8	12.3	10.5	16.5	14.1	10.0	8.2	8.0	7.6
105	15.5	17.1	13.5	12.8	11.8	11.5	9.5	12.5	10.0	9.1	8.5	8.6
120	9.5	11.6	11.5	10.8	11.3	10.5	8.5	8.3	7.8	6.7	7.5	6.6
135	--	--	--	--	--	--	5.0	15.3	4.5	4.9	5.1	4.7
150	--	--	--	--	--	--	--	--	--	--	--	--

Soil Control

Depth (cm)	L21						L23					
	4/7	5/9	6/9	7/7	8/2	9/8	4/7	5/9	6/9	7/7	8/2	9/8
15	23.5	13.9	6.0	4.5	3.8	3.8	11.5	10.9	4.5	3.3	2.9	2.8
30	27.5	18.9	11.3	9.7	8.7	8.5	24.5	18.0	9.6	8.5	7.2	7.0
45	27.0	18.9	11.8	9.2	8.7	9.0	25.5	18.0	12.1	9.9	8.7	9.0
60	25.5	18.9	12.3	9.2	9.2	9.0	27.5	20.0	14.8	10.5	9.7	9.0
75	24.5	18.9	12.3	9.2	9.2	8.0	27.0	21.6	15.7	11.5	11.3	10.9
90	20.0	16.6	11.8	9.2	8.2	7.5	27.0	21.7	12.1	11.5	11.3	10.9
105	19.0	17.2	12.8	8.7	8.7	8.5	--	--	--	--	--	--
135	20.0	18.3	13.8	9.7	9.7	9.5	--	--	--	--	--	--
150	--	15.5	13.8	9.7	9.7	9.0	--	--	--	--	--	--

* Values are in percent moisture by volume as determined from a standard soil moisture curve.

APPENDIX TABLE 8. MOISTURE MEASUREMENTS (NEUTRON PROBE) FROM THE LOW-ELEVATION LYSIMETER, NORTH-ASPECT, 2% SLOPE TREATMENT, 1978.

Depth (cm)	Paraho Spent Shale											
	L2						L4					
	4/7	5/9	6/9	7/7	8/2	9/8	4/7	5/9	6/9	7/7	8/2	9/8
15	15.5*	16.6	7.3	11.6	10.7	9.0	22.0	18.9	13.8	11.6	10.0	7.4
30	17.5	16.6	13.7	13.2	13.4	13.0	15.5	17.1	13.8	13.2	12.7	11.3
45	17.5	16.4	15.2	14.2	14.5	13.5	14.0	14.3	13.8	12.1	12.7	11.3
60	18.5	17.7	15.7	14.7	15.0	15.1	16.0	17.1	14.4	13.2	14.3	13.8
75	21.0	20.1	17.8	17.3	18.3	17.8	17.0	18.9	16.5	15.2	15.3	15.4
90	22.5	21.2	19.0	19.0	19.5	17.8	17.5	18.3	17.0	15.7	16.4	15.4
105	22.5	21.2	19.0	19.5	19.5	17.8	19.5	22.5	18.1	18.4	17.5	17.5
120	21.0	20.6	18.4	17.8	18.3	17.3	19.5	21.3	18.1	17.3	18.0	16.5
135	21.5	20.1	19.0	17.8	18.3	17.8	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	20 cm Soil Cover/Paraho											
	L6						L8					
	4/7	5/9	6/9	7/7	8/2	9/8	4/7	5/9	6/9	7/7	8/2	9/8
15	18.5	20.4	11.0	7.8	7.6	7.3	7.0	11.4	8.1	3.1	2.3	2.8
30	18.0	18.6	12.5	10.7	9.1	9.2	16.5	22.9	12.0	10.0	8.5	8.8
45	16.5	18.1	13.5	11.1	11.6	10.6	19.5	22.2	15.0	13.5	13.0	12.3
60	11.0	15.7	12.5	12.1	11.6	11.1	18.5	20.4	16.0	15.0	13.5	14.9
75	10.0	14.7	12.5	12.1	12.1	11.6	16.5	18.1	14.5	14.0	13.0	13.3
90	10.0	14.1	13.0	12.5	12.1	12.1	16.0	16.9	14.0	14.0	13.5	13.8
105	--	--	13.5	--	--	--	10.5	16.9	14.0	13.5	13.5	13.8
120	--	--	--	--	--	--	12.5	18.1	15.5	16.0	14.6	15.4
135	--	---	--	--.	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	40 cm Soil Cover/Paraho											
	L10						L12					
	4/7	5/9	6/9	7/7	8/2	9/8	4/7	5/9	6/9	7/7	8/2	9/8
15	18.0	19.2	7.4	5.9	4.7	5.0	18.5	18.0	9.3	9.0	7.1	6.9
30	21.0	21.6	10.3	9.2	8.6	8.3	19.0	18.0	10.8	9.5	9.1	8.3
45	19.5	22.8	10.8	8.7	8.6	7.8	17.5	17.5	9.3	9.0	8.1	7.8
60	17.0	19.2	11.7	9.7	8.1	7.4	17.0	18.6	11.8	9.9	9.6	8.8
75	9.0	14.0	9.8	9.2	8.6	7.8	17.5	18.0	13.3	12.0	11.6	10.3
90	7.5	12.5	9.3	9.2	9.1	8.8	13.5	16.9	12.8	12.5	11.6	11.3
105	7.5	12.5	9.8	10.7	10.0	9.8	12.5	14.6	12.8	12.5	11.1	10.3
120	7.5	13.0	12.3	12.1	12.1	12.3	11.5	14.6	12.8	13.0	12.7	11.8
135	--	--	--	--	--	--	8.0	10.4	9.8	--	9.6	9.3
150	--	--	--	--	--	--	--	--	--	--	--	--

* Values are in percent moisture by volume as determined from a standard soil moisture curve.

† Indicates the application of additional sprinkler irrigations - 4/10/78 - average of 8 inches of applied to simulate spring snowmelt.
5/09/78 - average of 1.2 inches applied
6/27/78 - average of 1.2 inches applied

APPENDIX TABLE 8. CONTINUED.

Depth (cm)	60 cm Soil Cover/Paraho											
	L14						L16					
	4/7	5/9	6/9	7/7	8/2	9/8	4/7	5/9	6/9	7/7	8/2	9/8
15	18.5*	21.6	9.7	9.1	7.8	7.0	16.0	15.2	8.7	6.3	5.1	5.0
30	20.5	22.2	10.7	9.5	9.8	9.0	17.5	15.0	9.7	9.2	9.0	8.8
45	18.5	20.4	11.1	9.5	9.3	9.5	17.5	15.7	10.7	9.7	9.5	9.3
60	18.5	21.6	11.6	9.5	9.3	9.5	17.0	20.4	12.6	10.7	10.5	9.8
75	17.5	21.6	13.2	11.0	10.4	9.5	17.0	20.4	12.6	10.7	10.5	9.8
90	17.0	22.2	15.2	13.0	13.0	12.0	16.0	19.2	13.7	12.1	12.0	11.8
105	13.0	21.6	15.2	13.5	14.1	13.0	12.5	15.7	14.7	13.2	13.5	12.8
120	17.0	20.4	15.2	13.5	14.1	13.5	13.0	20.4	15.7	15.2	15.1	15.4
135	--	19.2	15.2	14.0	14.1	13.5	13.0	21.6	18.4	16.8	17.8	17.0
150	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	80 cm Soil Cover/Paraho											
	L18						L20					
	4/7	5/9	6/9	7/7	8/2	9/8	4/7	5/9	6/9	7/7	8/2	9/8
15	16.5	20.5	7.8	6.0	5.2	5.0	18.5	19.2	8.5	6.8	5.3	5.1
30	19.5	22.3	11.3	9.3	9.1	8.7	21.0	22.2	12.3	10.1	9.3	9.0
45	18.5	23.0	10.8	8.8	9.1	8.7	20.5	21.6	12.3	10.1	10.4	9.5
60	18.0	21.7	11.3	9.3	8.6	8.2	20.5	22.7	13.7	10.1	10.4	9.5
75	16.5	21.7	11.3	9.8	9.1	8.7	21.5	23.4	15.3	10.7	9.8	9.0
90	16.5	23.0	13.8	12.8	11.6	10.6	22.5	23.4	16.3	13.2	10.9	10.5
105	16.5	23.0	16.0	14.9	13.7	12.1	19.0	21.6	15.8	13.7	12.8	11.5
120	16.5	21.7	17.0	15.4	13.7	13.2	16.0	15.2	12.8	11.9	10.9	10.9
135	15.0	21.7	17.0	16.0	15.9	14.2	17.0	15.2	12.3	12.1	12.0	10.9
150	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	Soil Control											
	L22						L24					
	4/7	5/9	6/9	7/7	8/2	9/8	4/7	5/9	6/9	7/7	8/2	9/8
15	17.0	14.7	8.8	8.2	7.4	6.5	18.5	13.6	7.3	6.0	4.7	5.1
30	19.0	15.7	10.3	9.7	9.0	9.0	20.0	15.7	10.1	8.3	7.6	7.0
45	19.0	18.0	12.8	10.1	10.5	10.5	17.5	14.7	9.2	7.4	7.1	7.0
60	17.5	19.8	12.9	10.7	10.5	9.9	17.5	17.5	10.6	8.8	8.6	7.0
75	18.5	21.6	12.3	11.6	11.6	9.5	20.5	21.6	12.6	10.8	10.0	9.9
90	20.0	21.6	13.7	12.1	12.1	11.5	22.5	24.0	15.7	11.8	11.1	10.5
105	20.5	24.0	14.4	12.1	12.7	12.0	23.0	24.7	16.8	12.8	11.6	10.5
120	20.5	22.7	14.9	12.6	13.2	11.5	--	--	--	--	--	--
135	--	22.2	14.9	12.6	12.1	10.9	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--

* Values are in percent moisture by volume as determined from a standard soil moisture curve.

APPENDIX TABLE 9. VEGETATIVE ANALYSIS (TRANSECT METHOD) OF THE HIGH-ELEVATION LYSIMETER, SOUTH-ASPECT, 25% SLOPE TREATMENTS, 1979.

Species	Paraho Spent Shale		20 cm Soil Cover/Paraho		40 cm Soil Cover/Paraho		60 cm Soil Cover/Paraho		80 cm Soil Cover/Paraho		Soil Control	
	H1	H3	H5	H7	H9	H11	H13	H15	H17	H19	H21	H23
PERENNIAL GRASSES												
Western wheatgrass	41*	79	706	677	737	640	694	706	598	927	939	1008
Bluebunch wheatgrass	-	-	-	33	-	-	-	-	-	18	-	-
Intermediate wheatgrass	-	-	-	-	-	-	-	-	-	-	-	-
Sherman big bluegrass	-	-	-	-	-	-	-	-	-	-	-	-
FORBS												
Utah sweetvetch	-	-	8	13	20	15	5	-	-	-	-	11
Penstemon	-	-	10	10	6	7	-	-	-	-	-	-
SHRUBS												
Fourwing saltbush	-	-	-	-	-	-	-	-	-	-	-	-
OTHER SPECIES												
Cheatgrass	-	66	231	178	258	357	380	255	168	275	-	20
Kochia	445	414	-	-	-	-	-	-	-	-	-	-
Goosefoot	18	-	-	-	-	-	-	-	-	-	-	-
Plantain	-	-	5	-	10	6	-	-	107	-	23	-
Mustard	-	-	-	-	-	-	-	-	-	-	-	-
Thistle	-	-	-	-	-	-	-	-	-	-	-	-
Hordeum	-	-	-	-	10	-	-	-	-	-	-	-
Mint	-	-	-	-	-	-	-	-	-	-	-	-
Salt cedar	-	15	-	-	-	-	-	-	-	-	18	-
Russian thistle	3	37	-	-	-	-	-	-	-	-	-	-
NO VEGETATIVE COVER	339	406	51	94	116	56	49	173	252	48	13	-
LITTER	184	15	62	-	34	21	50	48	15	35	57	-

* Values are in total cm of above ground vegetative cover by species. Each plot represents the total of three transect lines approximately 350 cm in length each. Line 1 in upper, line 2 in middle, and line 3 in lower 1/3 of each plot.

APPENDIX TABLE 10. VEGETATION ANALYSIS (TRANSECT METHOD) OF THE HIGH-ELEVATION LYSIMETER, NORTH-ASPECT, 2% SLOPE TREATMENTS, 1979.

Species	Paraho Spent Shale		20 cm Soil Cover/Paraho		40 cm Soil Cover/Paraho		60 cm Soil Cover/Paraho		80 cm Soil Cover/Paraho		Soil Control	
	H2	H4	H6	H8	H10	H12	H14	H16	H18	H20	H22	H24
PERENNIAL GRASSES												
Western wheatgrass	28*	64	720	690	668	595	542	686	531	681	903	984
Bluebunch wheatgrass	-	-	28	-	3	-	-	-	-	-	-	-
Intermediate wheatgrass	-	-	-	-	-	-	-	-	-	-	20	-
Sherman big bluegrass	-	-	-	-	26	-	-	-	-	-	-	-
FORBS												
Utah sweetvetch	-	-	2	13	6	-	-	8	-	12	5	22
Penstemon	-	-	-	-	-	-	-	-	-	-	3	9
SHRUBS												
Fourwing saltbush	-	-	-	-	-	-	-	-	-	-	-	-
OTHER SPECIES												
Cheatgrass	91	8	90	134	320	473	248	259	182	169	20	-
Kochia	426	397	-	-	-	-	-	-	-	-	-	-
Goosefoot	2	-	-	-	-	-	-	-	-	-	-	-
Plantain	-	-	-	-	-	-	29	14	73	107	24	-
Mustard	-	-	-	-	-	-	2	35	-	-	-	-
Thistle	-	2	-	3	-	-	-	-	-	-	-	-
Hordeum	-	-	-	-	-	-	-	-	8	12	-	-
Mint	-	-	-	-	-	-	-	-	-	-	-	-
Salt cedar	-	-	-	-	-	-	-	-	-	-	-	-
Russian thistle	6	-	-	-	-	-	-	-	7	-	-	-
NO VEGETATIVE COVER	297	315	66	32	29	51	137	19	152	98	10	-
LITTER	186	246	121	126	66	47	99	95	43	21	49	14

* Values are in total cm of above ground vegetative cover by species. Each plot represents the total of three transect lines approximately 350 cm in length each. Line 1 in upper, line 2 in middle, and line 3 in lower 1/3 of each plot.

APPENDIX TABLE 11. VEGETATIVE ANALYSIS (TRANSECT METHOD) OF THE LOW-ELEVATION LYSIMETER, SOUTH-ASPECT, 25% SLOPE TREATMENTS, 1979.

Species	Paraho Spent Shale		20 cm Soil Cover/Paraho		40 cm Soil Cover/Paraho		60 cm Soil Cover/Paraho		80 cm Soil Cover/Paraho		Soil Control	
	L1	L3	L5	L7	L9	L11	L13	L15	L17	L19	L21	L23
PERENNIAL GRASSES												
Western wheatgrass	-	3*	59	37	35	-	-	7	22	23	433	294
Bluebunch wheatgrass	-	-	-	-	-	-	-	-	-	-	32	-
Indian ricegrass	-	-	-	-	-	-	-	-	-	-	31	35
Galleta	-	-	243	293	159	203	146	166	163	253	68	160
FORBS												
Utah sweetvetch	-	-	-	-	-	-	-	-	-	-	-	-
SHRUBS												
Fourwing saltbush	45	-	6	-	16	7	3	-	16	-	147	158
Big sage	-	-	-	-	-	-	-	-	-	-	-	-
Winterfat	-	-	-	-	-	-	-	-	-	-	-	51
OTHER SPECIES												
Cheatgrass	-	-	403	361	488	675	693	686	533	469	66	192
Kochia	80	101	-	-	2	2	42	4	-	-	5	-
Goosefoot	-	-	-	-	-	-	-	-	-	8	-	8
Plantain	-	-	-	-	-	-	-	-	-	-	-	-
Mustard	-	-	-	-	10	7	-	15	14	14	9	-
Hordeum	-	-	-	-	-	-	-	-	-	-	-	-
Salt cedar	-	7	-	-	-	-	-	-	-	-	-	-
Alfalfa	-	-	-	-	15	-	-	-	-	-	13	5
Gumweed	-	-	-	-	-	-	-	-	-	-	-	-
Russian thistle	216	150	-	-	-	53	124	35	61	101	5	-
NO VEGETATIVE COVER	478	729	235	213	356	176	122	106	171	321	60	50
LITTER	181	30	179	205	63	55	46	75	99	30	154	92

* Values are in total cm of above ground vegetative cover by species. Each plot represents the total of three transect lines approximately 350 cm in length each. Line 1 in upper, line 2 in middle, and line 3 in lower 1/3 of each plot.

APPENDIX TABLE 12. VEGETATIVE ANALYSIS (TRANSECT METHOD) OF THE LOW-ELEVATION LYSIMETER, NORTH-ASPECT, 2% SLOPE TREATMENTS, 1979.

Species	Paraho Spent Shale		20 cm Soil Cover/Paraho		40 cm Soil Cover/Paraho		60 cm Soil Cover/Paraho		80 cm Soil Cover/Paraho		Soil Control	
	L2	L4	L6	L8	L10	L12	L14	L16	L18	L20	L22	L24
PERENNIAL GRASSES												
Western wheatgrass	-	2*	212	149	343	218	179	81	268	250	236	522
Bluebunch wheatgrass	-	-	-	-	-	-	-	-	-	-	-	-
Indian ricegrass	-	-	-	-	-	-	-	13	-	-	15	59
Galleta	-	-	-	-	-	-	117	47	207	266	130	82
FORBS												
Utah sweetvetch	-	-	-	-	-	-	-	5	-	-	-	5
SHRUBS												
Fourwing saltbush	5	9	16	19	-	-	15	42	13	21	7	74
Big sage	-	-	-	-	-	-	-	-	-	-	13	-
Winterfat	-	6	-	-	-	-	7	-	-	-	-	38
OTHER SPECIES												
Cheatgrass	-	16	776	848	614	769	509	745	346	76	510	48
Kochia	195	131	-	-	-	-	-	-	3	19	-	-
Goosefoot	-	-	-	-	-	-	-	-	6	22	-	-
Plantain	-	-	-	-	-	-	-	-	-	-	29	-
Mustard	-	-	-	-	4	6	-	-	-	7	-	-
Hordeum	-	-	-	-	-	-	-	-	8	-	-	-
Salt cedar	-	12	-	-	-	-	-	-	-	-	-	-
Alfalfa	-	-	12	-	-	-	-	-	-	10	23	27
Gumweed	-	-	-	10	-	-	-	-	-	-	-	-
Russian thistle	20	106	-	-	-	-	3	-	-	2	-	-
NO VEGETATIVF COVER	724	485	66	30	65	84	102	57	171	210	7	126
LITTER	44	248	51	30	15	39	128	107	85	182	78	77

* Values are in total cm of above ground vegetative cover by species. Each plot represents the total of three transect lines approximately 350 cm in length each. Line 1 in upper, line 2 in middle, and line 3 in lower 1/3 of each plot.

APPENDIX TABLE 13. MOISTURE MEASUREMENTS (NEUTRON PROBE) FROM THE HIGH-ELEVATION LYSIMETER, SOUTH-ASPECT, 25% SLOPE TREATMENTS, 1979.

Depth (cm)	Paraho Spent Shale																	
	H1									H3								
	4/23	† 5/2	5/16	† 6/6	6/14	† 6/29	7/16	8/17	9/13	4/23	† 5/2	5/16	† 6/6	6/14	† 6/29	7/16	8/17	9/13
15	17.8*	19.0	18.3	16.5	14.3	9.0	7.5	5.3	4.3	21.3	17.8	23.0	19.5	18.3	15.0	6.0	8.3	6.8
30	17.8	25.0	18.3	16.5	16.5	13.0	10.5	6.3	6.5	24.0	24.3	23.0	20.8	19.0	17.8	10.0	11.8	9.8
45	17.8	29.5	18.3	16.5	16.5	14.0	12.0	8.8	8.0	19.0	26.3	19.0	17.8	17.8	15.5	12.0	13.3	11.8
60	16.5	29.5	17.3	16.5	17.0	14.0	12.0	12.8	10.5	17.0	28.0	16.3	15.0	16.0	14.5	13.0	12.8	12.8
75	16.5	29.5	17.3	15.5	16.0	15.3	12.0	13.3	13.5	16.5	28.0	16.3	14.5	14.3	14.5	13.0	13.3	12.8
90	17.8	30.3	18.3	17.8	17.0	17.3	11.5	16.5	16.8	17.8	27.5	17.3	16.5	16.0	16.0	13.0	12.8	15.5
105	20.8	29.5	21.8	20.8	19.0	20.0	11.0	20.0	19.5	20.0	26.8	18.3	17.8	17.0	16.5	13.5	16.0	16.0
120	--	24.3	--	21.8	--	21.8	11.0	--	--	21.3	26.8	20.0	21.3	19.0	19.0	15.8	18.3	18.3
135	--	--	--	--	--	--	--	--	--	--	26.8	--	--	--	--	17.3	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	20 cm Soil Cover/Paraho																	
	H5									H7								
	4/23	† 5/2	5/16	† 6/6	6/14	† 6/29	7/16	8/17	9/13	4/23	† 5/2	5/16	† 6/6	6/14	† 6/29	7/16	8/17	9/13
15	13.3	19.5	15.5	9.3	9.0	8.0	7.5	9.3	8.3	17.0	23.0	19.0	11.8	11.0	10.0	8.5	10.3	9.5
30	18.3	23.0	20.0	11.8	10.5	10.0	10.5	10.3	9.8	20.8	22.5	21.8	15.5	13.3	11.5	11.5	11.3	10.5
45	22.0	23.8	21.8	17.3	15.5	13.0	11.5	12.3	11.3	22.0	25.5	22.5	17.8	16.0	14.5	11.0	12.3	12.5
60	20.8	24.3	22.5	17.8	17.0	15.8	11.0	14.0	13.3	19.5	23.5	21.3	17.8	17.0	16.3	12.0	14.5	14.0
75	13.8	24.3	14.5	13.3	13.8	11.5	12.5	11.8	11.3	18.3	24.8	19.0	16.0	15.5	14.0	13.5	13.3	13.5
90	10.0	25.0	10.8	9.8	9.5	8.0	16.8	9.8	8.3	18.3	24.8	20.0	15.5	16.0	15.3	17.3	15.0	13.5
105	10.5	21.3	14.5	10.3	10.0	9.5	15.8	9.3	9.3	20.8	24.3	20.0	17.3	17.8	16.8	18.3	15.5	15.8
120	16.0	20.0	--	14.5	11.5	13.0	15.8	--	--	19.5	23.0	20.0	19.0	19.0	18.3	17.8	17.3	16.3
135	--	21.8	--	--	--	--	17.8	--	--	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	40 cm Soil Cover/Paraho																	
	H9									H11								
	4/23	† 5/2	5/16	† 6/6	6/14	† 6/29	7/16	8/17	9/13	4/23	† 5/2	5/16	† 6/6	6/14	† 6/29	7/16	8/17	9/13
15	14.5	23.8	17.8	9.8	9.3	8.0	9.0	9.3	8.8	18.3	21.8	20.0	11.3	11.0	9.5	8.5	9.8	9.8
30	19.0	25.5	21.3	12.3	11.3	10.5	10.5	9.8	10.3	20.8	23.8	21.3	12.8	12.0	11.0	10.5	9.8	9.8
45	22.5	26.3	25.0	17.8	15.5	12.5	10.5	10.8	11.3	20.8	23.0	19.5	15.0	13.8	11.0	10.5	10.3	10.8
60	24.3	26.8	25.0	20.8	17.8	14.0	12.0	14.5	14.5	17.0	22.5	16.3	15.5	14.3	12.0	11.0	11.8	11.8
75	21.3	26.8	23.8	20.0	19.0	16.3	16.8	14.5	14.5	17.0	22.5	17.3	15.5	14.8	14.0	13.0	12.3	12.3
90	19.0	25.0	21.3	18.3	17.8	15.8	16.8	15.5	15.0	16.0	21.3	16.3	15.5	14.8	14.0	15.3	13.3	12.8
105	20.0	21.8	21.8	19.0	17.0	17.3	17.3	16.5	16.0	18.3	22.5	19.5	17.3	16.5	17.3	17.8	15.0	16.0
120	19.0	21.8	20.0	17.8	17.3	17.3	16.3	15.5	16.0	--	22.5	--	--	--	--	17.8	--	--
135	--	21.3	--	--	--	--	16.8	--	--	--	21.3	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

* Values are in percent moisture by volume as determined from a standard soil moisture curve.

† Indicates the application of additional sprinkler irrigations - 4/24/79 - average of 8 inches applied to simulate spring snowmelt.
5/21/79 - average of 0.9 inch applied
6/18/79 - average of 1.0 inch applied

APPENDIX TABLE 13. CONTINUED.

Depth (cm)	60 cm Soil Cover/Paraho																		
	H13									H15									
	4/23	+ 5/2	5/16	+ 6/6	6/14	+ 6/29	7/16	8/17	9/13	4/23	+ 5/2	5/16	+ 6/6	+ 6/14	+ 6/29	+ 7/16	8/17	9/13
15	13.8*	22.5	17.8	8.8	9.5	9.3	8.3	10.3	9.3	17.0	20.0	19.5	11.5	10.8	10.0	10.3	9.8	9.8
30	19.5	23.0	22.5	12.8	11.0	11.3	9.8	11.3	10.8	20.8	21.8	23.5	13.0	12.3	11.5	10.8	11.3	10.8
45	20.8	21.3	22.5	16.0	13.3	12.3	10.3	11.3	10.8	22.0	24.3	24.3	15.8	12.8	11.5	13.3	11.3	11.3
60	20.8	17.3	21.3	17.3	15.5	12.3	9.8	11.3	11.8	25.8	26.8	25.5	20.5	15.0	14.0	16.0	12.3	12.8
75	20.8	17.8	21.8	19.5	17.0	15.0	13.3	13.3	14.0	27.0	26.3	25.5	23.0	20.0	16.8	16.0	15.5	16.0
90	20.8	16.5	21.3	19.5	18.3	16.5	12.8	15.5	15.0	24.5	21.8	23.5	20.5	19.5	18.3	17.8	17.3	16.5
105	20.8	19.5	21.3	20.0	19.0	17.3	14.8	17.3	17.3	22.0	21.8	20.5	20.0	18.3	18.3	16.0	16.5	16.5
120	19.5	20.0	21.8	20.0	19.5	19.0	--	17.8	17.8	19.5	19.5	19.5	17.8	17.8	15.8	--	16.0	16.5
135	--	--	--	--	--	--	--	--	--	19.5	--	19.5	17.8	17.3	17.3	--	16.0	16.0
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	80 cm Soil Cover/Paraho																		
	H17									H19									
	4/23	+ 5/2	5/16	+ 6/6	6/14	+ 6/29	7/16	8/17	9/13	4/23	+ 5/2	5/16	+ 6/6	+ 6/14	+ 6/29	7/16	8/17	9/13
15	19.5	23.0	21.3	12.3	10.3	9.0	9.5	10.0	9.3	13.8	21.3	16.3	9.3	8.3	8.3	7.0	8.3	7.8
30	22.0	23.0	21.8	14.5	11.8	12.0	11.0	11.0	10.8	19.5	23.8	21.3	12.3	11.3	11.3	10.0	9.8	10.8
45	23.0	23.0	23.5	19.0	15.0	13.5	13.5	12.5	12.3	22.0	24.3	22.5	14.0	11.8	12.3	10.5	9.8	10.8
60	24.5	20.5	25.5	21.3	19.0	14.5	16.3	13.0	12.8	22.0	21.3	24.3	17.8	13.5	12.3	13.5	10.8	10.8
75	24.5	18.3	25.5	22.5	20.0	17.3	14.5	13.5	12.8	23.0	14.5	24.3	20.8	16.5	14.5	11.5	12.3	11.3
90	24.5	19.5	24.8	23.0	20.8	19.5	15.3	16.3	15.0	24.5	11.8	24.8	23.8	22.5	19.0	9.0	16.0	16.0
105	23.0	20.0	23.0	23.8	21.3	19.5	16.8	17.3	16.5	22.0	11.3	20.5	20.0	20.0	18.3	9.0	16.5	15.5
120	22.0	20.5	21.8	21.3	20.0	19.5	17.3	17.3	17.8	18.3	15.5	18.3	17.3	17.8	16.5	--	15.5	15.0
135	--	--	--	--	--	--	--	--	--	19.5	--	19.5	19.5	20.0	19.0	--	17.3	17.3
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	Soil Control																		
	H21									H23									
	4/23	+ 5/2	5/16	+ 6/6	6/14	+ 6/29	7/16	8/17	9/13	4/23	+ 5/2	5/16	+ 6/6	6/14	+ 6/29	7/16	8/17	9/13
15	14.5	25.0	15.3	8.3	8.0	7.0	9.0	7.0	7.8	13.3	20.8	14.0	9.8	8.5	7.5	4.3	7.3	7.0
30	19.0	24.3	21.8	14.5	12.8	11.5	16.3	11.0	11.3	21.3	20.8	21.8	12.8	12.0	10.5	8.5	10.8	9.5
45	23.8	21.3	24.3	15.5	13.8	12.5	14.5	12.5	11.8	26.3	19.5	21.3	16.0	14.3	12.5	11.0	11.8	10.5
60	25.0	16.3	26.8	19.0	14.8	13.5	13.5	12.5	12.8	27.5	19.0	21.7	18.3	16.0	13.0	13.0	11.8	11.0
75	26.3	16.5	27.3	22.5	17.8	15.3	13.5	13.0	13.3	26.3	18.3	28.0	21.3	16.0	13.5	14.5	11.3	11.5
90	25.0	17.8	27.3	22.5	20.8	15.3	15.8	12.0	12.8	25.0	19.0	28.0	23.8	17.8	12.5	16.8	10.8	10.5
105	23.8	20.8	27.3	23.8	23.0	15.8	16.3	12.5	12.8	23.8	23.0	28.0	24.3	20.8	12.5	20.5	10.8	10.5
120	22.5	23.0	26.0	23.8	23.0	19.5	19.5	13.0	14.0	16.5	--	23.5	20.8	20.8	13.0	--	10.8	10.5
135	17.8	--	26.0	25.0	24.5	21.3	--	13.5	13.3	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

* Values are in percent moisture by volume as determined from a standard soil moisture curve.

\+ Indicates the application of additional sprinkler irrigations - 4/24/79 - average of 8 inches applied to simulate spring snowmelt
5/21/79 - average of 0.9 inch applied
6/18/79 - average of 1.0 inch applied

APPENDIX TABLE 14. MOISTURE MEASUREMENTS (NEUTRON PROBE) FROM THE HIGH-ELEVATION LYSIMETER, NORTH-ASPECT, 2% SLOPE TREATMENTS, 1979.

Paraho Spent Shale

Depth (cm)	H2									H4								
	4/23	+ 5/2	5/16	+ 6/6	6/14	+ 6/29	7/16	8/17	9/13	4/23	+ 5/2	5/16	+ 6/6	6/14	+ 6/29	7/16	8/17	9/13
15	11.5*	15.0	13.3	9.3	8.3	6.0	3.0	4.3	3.8	20.0	20.8	20.0	16.5	14.5	13.0	9.5	9.5	7.0
30	18.3	20.8	20.0	17.8	16.0	14.0	9.3	8.0	6.5	15.3	16.0	16.5	13.3	13.3	12.5	11.0	10.0	9.0
45	17.0	20.0	18.3	15.5	15.5	14.0	13.3	12.0	10.0	9.8	11.3	10.8	8.8	9.3	9.0	8.5	9.0	7.5
60	17.0	20.0	17.8	15.5	15.5	15.3	14.0	14.0	12.0	8.8	9.3	9.3	8.6	7.8	8.0	7.0	7.0	7.0
75	20.8	22.5	22.5	20.0	20.0	18.3	16.5	17.3	17.3	9.8	9.8	9.3	8.8	8.3	9.0	8.5	8.0	8.5
90	24.5	25.0	24.3	21.8	21.8	19.5	21.3	18.3	17.8	15.3	15.5	15.0	14.0	12.8	13.0	13.0	12.0	12.0
105	23.0	26.8	24.3	24.3	22.5	21.3	20.8	19.5	19.5	20.0	19.0	17.8	18.3	17.3	17.3	15.8	15.8	14.5
120	22.0	25.5	23.0	23.0	22.5	20.5	20.0	19.5	18.3	--	--	--	--	--	--	--	--	--
135	22.0	23.8	23.0	21.8	20.8	20.0	19.5	19.5	18.3	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

20 cm Soil Cover/Paraho

Depth (cm)	H6									H8								
	4/23	+ 5/2	5/16	+ 6/6	6/14	+ 6/29	7/16	8/17	9/13	4/23	+ 5/2	5/16	+ 6/6	6/14	+ 6/29	7/16	8/17	9/13
15	17.0	19.5	18.3	9.8	9.3	7.3	6.3	8.3	7.3	15.5	21.3	15.5	9.3	8.3	8.0	7.0	9.3	8.3
30	22.0	22.5	21.8	15.5	13.3	12.3	11.3	11.3	10.8	19.0	21.8	21.3	13.3	11.8	11.0	9.5	10.8	10.3
45	20.8	23.0	21.3	16.5	16.0	14.5	13.3	13.3	13.3	19.0	21.8	20.0	16.0	14.5	13.0	12.0	12.8	11.3
60	17.0	17.3	17.3	15.5	14.5	14.0	12.8	13.3	13.3	14.5	16.5	14.5	12.8	13.3	12.0	11.5	11.3	11.8
75	14.8	15.8	15.3	14.5	13.3	12.8	12.3	12.3	12.3	11.3	11.8	11.3	10.8	10.3	9.5	9.5	9.3	9.3
90	12.8	14.0	14.0	12.8	12.3	12.3	11.8	11.3	11.8	11.3	11.8	11.3	10.3	9.8	10.5	9.0	9.3	9.3
105	14.8	14.5	14.0	12.3	12.3	12.3	11.8	11.3	11.3	19.0	18.3	16.5	17.3	15.0	16.3	15.8	14.0	15.5
120	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
135	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

40 cm Soil Cover/Paraho

Depth (cm)	H10									H12								
	4/23	+ 5/2	5/16	+ 6/6	6/14	+ 6/29	7/16	8/17	9/13	4/23	+ 5/2	5/16	+ 6/6	6/14	+ 6/29	7/16	8/17	9/13
15	16.0	22.5	17.8	9.8	9.5	9.0	7.8	9.0	7.8	19.5	21.8	18.3	11.0	10.3	9.3	7.8	10.0	9.5
30	18.3	24.3	21.3	12.3	11.0	10.5	10.3	10.0	10.8	19.5	22.5	21.8	13.0	12.3	10.3	9.8	10.5	10.5
45	19.5	21.3	19.5	14.0	12.8	11.0	10.3	10.0	10.3	24.5	25.5	24.3	16.7	14.5	11.8	10.3	11.5	10.5
60	20.8	22.[illegible]	20.5	17.3	16.0	14.5	12.3	11.5	10.3	24.5	25.0	24.3	20.5	17.8	15.5	14.0	13.0	13.0
75	23.0	24.[illegible]	21.8	20.8	18.3	16.7	16.5	15.3	15.5	22.0	20.8	19.5	17.8	16.0	15.0	15.0	13.5	13.5
90	24.5	26.3	25.5	22.5	20.8	19.0	18.3	17.3	17.8	18.3	20.8	17.3	15.3	15.0	14.5	14.5	13.5	13.5
105	25.8	26.8	25.5	23.8	21.3	21.8	20.0	19.5	20.0	20.8	21.3	19.5	17.3	16.5	16.0	15.5	15.3	15.8
120	--	--	--	--	--	--	--	--	--	25.8	27.5	24.8	21.3	20.0	21.3	20.8	17.8	17.8
135	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

* Values are in percent moisture by volume as determined from a standard soil moisture curve.

\+ Indicates the application of additional sprinkler irrigations - 6/24/79 - average of 8 inches applied to simulate spring snowmelt.
5/21/79 - average of 0.9 inch applied
6/18/79 - average of 1.0 inch applied

APPENDIX TABLE 14. CONTINUED.

Depth (cm)	60 cm Soil Cover/Paraho																	
	H14									H16								
	4/23	† 5/2	5/16 †	6/6	6/14	† 6/29	7/16	8/17	9/13	4/23	† 5/2	5/16 †	6/6	6/14	† 6/29	7/16	8/17	9/13
15	22.0*	23.0	20.5	10.5	10.0	8.3	7.5	8.5	8.3	18.3	21.3	19.5	9.8	8.5	9.0	7.0	9.5	8.0
30	23.0	23.8	21.3	12.8	10.0	10.8	9.3	9.5	9.3	20.8	24.3	23.0	12.8	11.5	11.5	10.5	10.5	9.5
45	23.0	23.8	21.3	15.0	11.5	10.8	9.8	10.0	10.3	22.0	25.0	24.3	15.5	12.8	11.0	10.5	10.5	10.5
60	19.5	21.3	20.0	17.3	13.8	10.8	9.8	9.5	9.8	22.0	24.3	22.5	16.5	14.3	11.0	9.5	10.0	10.0
75	19.0	19.0	18.3	16.5	14.8	13.3	12.3	11.0	10.8	19.5	20.8	19.0	16.5	14.8	12.0	11.0	10.5	11.0
90	17.0	17.8	16.3	16.0	14.8	12.8	12.8	12.0	11.8	13.8	15.0	14.0	12.3	12.0	10.0	10.5	11.0	10.0
105	17.0	17.3	17.3	15.5	14.8	14.5	12.8	13.0	12.3	12.8	14.5	12.5	11.8	11.5	10.5	10.5	11.0	9.5
120	20.8	21.3	19.5	19.0	17.0	17.8	17.8	16.8	17.3	14.8	15.5	15.3	14.5	12.8	13.0	13.5	13.0	12.5
135	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	80 cm Soil Cover/Paraho																	
	H18									H20								
	4/23	† 5/2	5/16	† 6/6	6/14	† 6/29	7/16	8/17	9/13	4/23	† 5/2	5/16	† 6/6	6/14	† 6/29	7/16	8/17	9/13
15	12.8	15.5	12.0	6.5	6.7	5.0	4.8	6.8	5.0	11.5	8.5	6.3	4.0	3.3	3.3	2.5	4.3	3.3
30	22.0	23.0	21.3	12.0	10.5	10.5	9.5	9.3	9.0	18.3	20.0	17.8	10.3	9.3	10.0	8.8	8.5	8.3
45	23.0	23.0	23.0	15.8	13.8	11.5	10.5	10.3	10.0	19.5	21.8	21.3	12.3	10.8	11.0	10.3	10.5	9.8
60	23.0	24.3	23.0	18.3	16.5	12.5	10.5	10.3	10.5	22.0	22.5	22.5	14.5	12.3	11.5	11.3	10.5	10.8
75	23.0	24.3	23.0	20.0	18.3	14.5	11.0	11.8	11.5	23.0	21.8	22.5	16.5	14.0	12.0	10.3	10.5	10.3
90	23.0	22.5	23.0	20.0	19.0	16.3	14.0	14.0	12.5	20.8	21.3	21.8	19.0	15.5	13.0	10.8	10.5	10.8
105	19.0	20.0	19.5	18.3	18.3	14.5	14.0	14.5	14.0	23.0	24.3	23.8	21.3	19.0	17.8	13.3	14.5	14.0
120	18.3	20.0	19.5	17.3	17.0	16.8	15.8	15.5	13.5	19.5	--	--	20.8	--	--	--	--	--
135	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	Soil Control																	
	H22									H24								
	4/23	† 5/2	5/16	† 6/6	6/14	† 6/29	7/16	8/17	9/13	4/23	† 5/2	5/16	† 6/6	6/14	† 6/29	7/16	8/17	9/13
15	13.8	16.0	12.8	7.3	5.8	4.3	4.3	6.0	5.5	11.5	14.5	11.3	6.0	5.5	4.3	4.8	5.0	4.8
30	20.8	25.5	23.8	12.8	10.8	10.5	9.8	10.5	10.5	22.0	23.8	21.8	12.0	10.5	10.0	8.5	8.5	8.5
45	24.5	25.5	26.3	15.0	12.3	11.5	12.8	12.0	11.5	23.0	25.5	23.8	15.3	12.0	10.0	9.5	9.0	8.5
60	23.0	25.5	25.5	16.5	13.3	12.0	11.8	11.5	11.5	25.0	26.3	26.3	17.8	16.5	12.0	11.0	10.0	10.0
75	25.8	26.3	26.3	19.0	16.0	12.0	12.3	12.0	12.0	25.8	26.3	27.5	20.5	19.5	14.5	12.5	11.5	11.5
90	25.8	26.3	25.5	21.8	17.8	14.5	13.3	12.5	12.5	25.8	28.0	26.8	21.3	21.3	14.5	13.0	12.0	11.5
105	24.5	26.8	25.5	23.8	20.0	17.3	14.5	13.0	12.5	24.5	27.5	26.3	21.8	22.0	17.3	13.5	12.0	11.5
120	23.0	27.5	25.5	23.8	22.5	19.0	16.0	13.0	12.5	24.5	26.3	26.3	22.5	22.5	18.3	15.3	13.0	11.5
135	22.0	27.5	26.3	23.8	22.5	20.5	16.5	14.0	12.5	24.5	28.0	28.0	23.5	23.8	21.8	16.8	14.0	12.5
150	16.0	28.0	28.8	26.3	24.3	21.8	20.0	15.8	14.0	--	--	--	--	--	--	--	--	--

* Values are in percent moisture by volume as determined from a standard soil moisture curve.

† Indicates the application of additional sprinkler irrigations - 4/24/79 - average of 8 inches applied to simulate spring snowmelt
5/21/79 - average of .09 inch applied
6/18/79 - average of 1.0 inch applied

APPENDIX TABLE 15. MOISTURE MEASUREMENTS (NEUTRON PROBE) FROM THE LOW-ELEVATION LYSIMETER, SOUTH-ASPECT, 25% SLOPE TREATMENTS, 1979.

Depth (cm)	Paraho Spent Shale											
	L1						L3					
	4/23	5/16	6/14	7/17	8/17	9/13	4/23	5/16	6/14	7/17	8/17	9/13
15	9.3*	10.3	5.3	2.5	3.5	3.3	17.8	19.0	10.8	4.5	5.3	5.5
30	14.5	15.0	9.3	5.0	5.5	4.8	21.3	20.5	16.0	9.8	8.3	8.0
45	15.5	16.5	12.3	10.5	10.5	8.8	23.0	20.5	17.8	13.8	11.8	12.0
60	17.8	17.8	15.0	14.0	13.3	11.8	22.5	21.3	18.3	15.8	16.5	16.0
75	19.0	17.8	15.0	16.3	16.0	14.0	23.0	21.3	19.0	16.8	16.5	17.8
90	20.0	19.0	17.8	16.8	17.0	16.5	22.0	21.3	19.5	17.3	16.5	17.5
105	20.0	19.5	17.8	17.3	17.0	16.0	22.0	21.3	19.5	18.5	17.8	17.5
120	18.3	18.3	17.8	16.8	17.0	15.5	22.0	20.5	19.5	17.8	18.3	18.3
135	--	--	--	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	20 cm Soil Cover/Paraho											
	L5						L7					
	4/23	5/16	6/14	7/17	8/17	9/13	4/23	5/16	6/14	7/17	8/17	9/13
15	3.3	4.3	3.3	1.5	3.5	3.3	14.5	16.3	8.5	7.5	9.5	7.8
30	17.8	18.8	9.3	7.3	8.5	7.3	19.0	17.3	12.8	11.5	10.5	11.3
45	20.5	20.0	14.5	10.8	10.5	10.3	21.8	20.0	18.3	15.3	13.8	14.5
60	21.8	20.0	15.5	12.8	12.8	12.3	22.5	21.3	18.3	16.8	17.0	16.0
75	15.3	14.5	12.3	11.8	11.0	12.3	20.0	20.0	17.8	16.8	16.5	16.5
90	13.0	12.8	11.3	10.3	11.5	10.8	20.0	19.5	17.8	17.3	17.0	17.8
105	13.0	14.8	11.8	11.8	11.5	11.8	21.8	20.0	19.0	19.0	18.3	19.5
120	15.8	15.5	14.3	13.3	13.8	12.8	21.8	20.0	20.8	20.0	18.3	19.5
135	--	--	--	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	40 cm Soil Cover/Paraho											
	L9						L11					
	4/23	5/16	6/14	7/17	8/17	9/13	4/23	5/16	6/14	7/17	8/17	9/13
15	11.3	10.5	6.5	4.8	6.5	5.8	15.3	16.3	7.5	5.5	9.5	6.3
30	19.0	18.3	10.5	10.0	9.5	8.3	21.5	20.5	11.5	9.0	9.5	8.3
45	19.0	18.3	12.8	10.0	10.5	10.3	22.3	20.5	13.3	9.0	10.0	9.3
60	21.3	19.5	16.5	12.0	13.8	12.3	22.8	21.8	15.5	12.5	12.0	11.8
75	21.3	20.0	17.8	15.8	14.8	14.5	24.5	21.8	17.0	14.5	14.8	13.3
90	22.5	20.0	18.3	16.3	16.0	16.5	21.5	19.5	17.0	15.3	14.8	14.0
105	21.8	19.5	18.3	16.3	16.5	16.0	21.0	18.3	16.0	15.2	14.8	13.3
120	20.0	19.0	18.3	16.3	16.0	15.0	18.5	17.8	16.5	15.3	14.3	14.5
135	--	--	17.0	--	--	--	15.8	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--

* Values are in percent moisture by volume as determined from a standard soil moisture curve.

APPENDIX TABLE 15. CONTINUED.

Depth (cm)	60 cm Soil Cover/Paraho											
	L13						L15					
	4/23	5/16	6/14	7/17	8/17	9/13	4/23	5/16	6/14	7/17	8/17	9/13
15	19.0*	17.8	8.0	7.3	9.5	6.8	17.3	17.3	9.0	6.5	8.3	6.3
30	20.8	20.0	11.5	10.3	9.5	8.8	22.5	22.5	12.0	10.3	9.3	9.8
45	22.5	20.5	12.8	11.3	10.0	9.8	22.5	21.8	13.8	9.8	10.3	9.8
60	23.0	21.8	15.5	11.8	10.5	10.3	23.8	23.0	16.5	10.3	9.3	9.3
75	20.8	18.8	14.8	11.8	10.5	9.3	23.0	22.5	18.3	12.3	10.3	9.3
90	16.5	16.3	14.3	12.3	10.5	9.3	22.5	20.5	18.3	14.3	13.3	11.8
105	16.5	15.8	14.8	11.8	11.5	9.8	21.3	--	18.3	14.8	13.3	12.8
120	14.8	15.3	14.8	13.3	12.8	11.8	18.5	--	--	--	--	--
135	--	--	--	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	80 cm Soil Cover/Paraho											
	L17						L19					
	4/23	5/16	6/14	7/17	8/17	9/13	4/23	5/16	6/14	7/17	8/17	9/13
15	16.5	16.5	8.3	6.0	8.5	6.8	15.0	15.3	6.5	5.0	6.8	5.3
30	23.8	21.3	11.3	10.0	9.5	9.5	21.8	21.8	11.0	9.0	7.8	8.3
45	22.5	21.3	12.3	11.0	10.5	10.0	21.3	20.5	11.0	9.5	9.3	8.8
60	22.5	21.3	14.5	11.5	10.0	10.5	21.8	20.5	11.5	9.5	9.3	8.8
75	23.8	21.8	19.0	13.0	10.0	10.0	20.0	18.3	12.8	8.5	8.8	8.3
90	21.8	21.8	18.3	14.0	11.5	10.5	18.3	18.3	15.5	9.5	8.8	7.8
105	19.0	19.8	17.3	14.5	13.3	12.0	19.0	18.3	16.5	12.0	11.3	9.3
120	17.8	19.8	16.5	14.5	13.8	12.0	16.0	16.8	16.0	13.0	11.8	11.8
135	--	--	--	--	--	--	7.8	11.0	12.0	10.5	11.8	11.3
150	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	Soil Control											
	L21						L23					
	4/23	5/16	6/14	7/17	8/17	9/13	4/23	5/16	6/14	7/17	8/17	9/13
15	13.3	12.0	6.5	4.8	7.5	5.0	9.3	8.3	4.0	2.8	4.3	3.8
30	21.3	19.5	10.5	9.0	9.5	8.5	19.0	17.8	10.0	7.5	8.8	7.8
45	22.5	19.5	11.5	9.5	9.5	9.5	19.5	17.8	11.5	8.5	9.3	9.3
60	21.3	19.0	12.0	9.0	8.5	9.0	20.8	20.0	12.0	10.0	9.3	9.8
75	20.0	18.3	12.0	8.5	9.0	9.0	22.5	20.0	13.8	11.5	10.3	10.3
90	16.5	16.3	12.8	8.0	9.0	8.5	21.3	20.8	14.8	11.0	10.3	10.8
105	12.3	14.0	12.0	8.5	8.5	8.5	--	--	--	--	--	--
120	9.8	11.5	12.0	9.5	9.0	9.0	--	--	--	--	--	--
135	--	--	--	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--

* Values are in percent moisture by volume as determined from a standard soil moisture curve.

APPENDIX TABLE 16. MOISTURE MEASUREMENTS (NEUTRON PROBE) FROM THE LOW-ELEVATION LYSIMETER, NORTH-ASPECT, 2% SLOPE TREATMENTS, 1979.

Depth (cm)	Paraho Spent Shale											
	L2						L4					
	4/23	5/16	6/14	7/17	8/17	9/13	4/23	5/16	6/14	7/17	8/17	9/13
15	16.0*	15.3	11.3	6.0	6.3	6.3	18.3	17.3	13.3	8.3	7.5	5.8
30	17.0	17.3	14.5	11.5	9.8	8.3	17.8	17.3	14.0	12.8	11.0	9.3
45	16.0	15.8	15.0	13.5	12.3	11.8	14.8	15.3	14.0	12.3	11.5	10.8
60	17.8	17.3	15.5	15.8	14.5	14.5	17.0	16.3	15.0	14.3	14.3	12.8
75	21.3	20.5	18.3	16.3	16.5	16.0	18.3	17.3	16.0	14.3	14.8	14.5
90	23.0	21.8	19.5	18.3	18.3	19.0	18.3	17.8	17.3	15.8	15.5	15.0
105	20.8	19.8	20.0	18.3	19.0	17.8	21.3	20.0	19.5	18.5	18.3	17.3
120	20.8	19.5	20.0	17.8	17.3	17.8	20.8	20.0	19.5	16.8	17.8	16.5
135	--	--	--	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	20 cm Soil Cover/Paraho											
	L6						L8					
	4/23	5/16	6/14	7/17	8/17	9/13	4/23	5/16	6/14	7/17	8/17	9/13
15	20.8	19.5	11.0	9.0	9.3	9.0	8.3	9.3	5.0	3.5	5.3	4.3
30	21.3	19.5	14.8	12.0	12.3	11.5	21.3	21.8	12.0	11.3	12.3	10.8
45	20.8	19.0	15.5	14.0	13.3	13.0	22.5	21.3	16.0	14.5	14.5	14.5
60	17.0	16.3	13.8	12.0	12.3	12.0	21.3	20.0	17.0	15.0	15.0	15.0
75	17.0	15.3	13.3	12.5	12.8	12.0	19.0	16.5	16.5	15.5	15.0	14.5
90	16.0	14.5	13.8	12.5	13.3	12.5	17.8	16.5	15.5	15.0	14.5	14.0
105	--	--	--	--	--	--	16.5	16.5	15.5	15.0	14.5	14.5
120	--	--	--	--	--	--	17.8	18.3	17.0	16.0	15.0	14.5
135	--	--	--	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	40 cm Soil Cover/Paraho											
	L10						L12					
	4/23	5/16	6/14	7/17	8/17	9/13	4/23	5/16	6/14	7/17	8/17	9/13
15	19.0	17.3	7.3	5.0	8.3	7.3	20.0	17.3	9.8	8.5	9.8	8.3
30	22.5	21.8	10.8	9.5	9.8	8.8	23.0	20.5	10.8	10.0	10.8	10.3
45	23.0	21.3	11.8	9.0	9.3	9.8	22.0	19.5	11.3	11.0	10.8	10.8
60	21.3	19.5	13.3	10.0	10.3	10.3	20.8	19.5	15.0	12.5	12.3	11.8
75	14.5	13.5	11.8	10.0	10.3	10.3	19.5	17.3	15.0	13.5	13.3	12.3
90	13.3	12.0	11.3	10.0	10.3	10.8	18.3	16.3	15.0	13.5	14.0	13.3
105	13.3	13.0	12.8	11.0	11.3	11.3	17.0	16.3	15.0	13.5	14.0	14.5
120	17.8	16.3	14.5	14.0	13.3	14.0	20.8	19.5	18.3	18.3	17.8	16.5
135	--	--	--	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--

* Values are in percent moisture by volume as determined from a standard soil moisture curve.

APPENDIX TABLE 16. CONTINUED.

Depth (cm)	60 cm Soil Cover/Paraho											
	L14						L16					
	4/23	5/16	6/14	7/17	8/17	9/13	4/23	5/16	6/14	7/17	8/17	9/13
15	22.5*	21.3	10.3	8.5	8.0	8.0	14.8	15.3	6.8	5.5	8.0	7.5
30	24.3	23.8	12.3	9.0	9.0	9.0	22.5	19.5	10.5	9.0	10.5	9.5
45	23.8	23.0	12.8	9.5	9.5	9.5	22.5	20.0	11.0	9.5	9.5	9.5
60	22.5	21.3	14.0	10.0	9.5	9.0	22.0	19.5	14.3	10.0	10.0	9.5
75	24.3	24.3	17.3	11.5	10.0	9.0	22.0	20.0	17.0	12.0	11.0	11.0
90	25.0	23.8	19.0	14.5	12.5	11.5	20.8	19.0	16.5	13.5	13.3	13.3
105	21.3	22.5	20.0	15.8	14.0	13.5	20.8	18.3	17.0	14.5	14.3	14.3
120	21.3	20.8	18.3	16.3	14.0	15.3	22.5	20.0	19.5	16.8	16.0	16.5
135	--	--	--	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	80 cm Soil Cover/Paraho											
	L18						L20					
	4/23	5/16	6/14	7/17	8/17	9/13	4/23	5/16	6/14	7/17	8/17	9/13
15	17.3	16.3	8.0	6.3	7.5	6.8	18.3	18.3	9.5	6.5	7.8	7.3
30	21.3	21.8	11.0	8.8	9.0	8.8	22.5	23.0	12.0	10.0	9.3	8.8
45	21.3	21.8	12.8	9.3	9.5	9.3	22.5	21.8	13.8	9.5	9.3	9.8
60	21.3	21.3	12.8	9.3	9.5	9.3	23.8	22.5	15.5	10.5	9.8	9.3
75	2..3	20.5	14.3	10.3	10.0	9.3	23.8	23.0	18.3	11.0	9.3	9.8
90	22.5	21.3	17.8	14.5	13.8	12.3	23.8	22.5	19.0	13.5	11.8	11.3
105	21.3	19.5	19.0	16.0	14.3	14.0	21.3	19.5	19.0	14.0	12.8	11.8
120	20.0	19.5	19.0	17.3	14.8	14.5	16.5	15.3	15.5	12.0	11.8	11.3
135	20.0	19.5	19.0	17.3	16.0	16.0	15.5	15.3	14.3	12.5	12.3	12.3
150	--	--	--	--	--	--	--	--	--	--	--	--

Depth (cm)	Soil Control											
	L22						L24					
	4/23	5/16	6/14	7/17	8/17	9/13	4/23	5/16	6/14	7/17	8/17	9/13
15	20.0	18.3	9.5	7.0	9.0	7.3	14.5	14.0	7.5	6.3	7.8	6.5
30	22.5	20.3	11.5	9.0	9.5	9.8	18.3	17.3	10.0	7.8	8.3	8.0
45	23.0	21.8	14.3	11.0	10.0	11.3	16.5	15.3	9.5	7.8	7.8	8.0
60	22.5	21.3	16.0	11.5	11.0	10.8	19.0	16.3	10.0	7.8	8.3	8.0
75	22.5	20.5	17.0	12.5	11.5	10.8	21.3	19.5	12.8	9.3	9.8	9.5
90	23.8	23.5	20.8	14.0	12.8	11.8	23.0	20.5	14.3	10.8	10.3	10.5
105	25.0	24.3	22.0	16.3	13.8	12.3	23.8	--	16.0	--	10.3	--
120	22.5	21.8	22.0	16.8	14.3	12.3	--	--	--	--	--	--
135	--	--	--	--	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--	--	--	--	--

* Values are in percent moisture by volume as determined from a standard soil moisture curve.

APPENDIX TABLE 17. SALINITY MEASUREMENTS (EC) OF CORE SAMPLES FROM THE HIGH-ELEVATION LYSIMETER TREATMENTS, OCTOBER 1979.

Depth (cm)	2% Slope - North Aspect							
	Paraho Spent Shale		20 cm Soil Cover/ Paraho		40 cm Soil Cover/ Paraho		Soil Control	
	H2	H4	H6	H8	H10	H12	H22	H24
Surface	5.5*	2.0	0.9	1.0	2.0	1.0	1.4	1.6
20	5.0	1.6	1.0	0.6	0.7	0.9	1.0	0.8
40	5.6	5.0	2.2	5.2	0.7	0.7	0.7	0.8
60	5.4	4.2	6.6	6.5	5.7	2.4	0.6	0.5
80	3.7	5.4	6.4	6.2	7.2	5.6	0.7	0.8
100	2.0	5.8	6.3	6.0	7.6	5.2	--	1.1
120	1.0	6.2	5.8	6.6	7.2	6.2	--	1.2
140	4.8	6.0	5.0	5.4	6.6	12.0	--	1.3
160	3.8	5.7	6.2	5.5	10.6	12.3	--	1.5

Depth (cm)	25% Slope - South Aspect							
	Paraho Spent Shale		20 cm Soil Cover/ Paraho		40 cm Soil Cover/ Paraho		Soil Control	
	H1	H3	H5	H7	H9	H11	H21	H23
Surface	1.5	1.1	0.1	1.0	1.2	0.8	1.6	0.6
20	1.2	1.8	0.6	0.8	0.8	0.9	0.7	0.8
40	5.0	5.4	3.1	3.4	0.7	0.6	0.6	0.5
60	6.2	7.2	5.5	3.5	2.4	4.0	0.5	0.6
80	6.8	5.7	7.0	7.2	7.3	5.3	0.7	0.7
100	5.0	6.8	5.6	6.8	6.4	5.8	0.7	0.6
120	6.3	3.8		6.5	5.7	5.5	0.7	0.7
140	5.4	3.8	6.8	6.2	5.5	7.6	0.9	0.9
160	6.2	5.4	4.4	6.5	8.4		0.9	1.0

* EC values are in mmhos/cm @25°C measured on a 1:1 spent shale or soil to water by weight sample.

-- No sample collected.

APPENDIX TABLE 18. SALINITY MEASUREMENTS (EC) OF CORE SAMPLES FROM THE LOW-LYSIMETER TREATMENTS, OCTOBER 1979.

Depth (cm)	2% Slope - North Aspect							
	Paraho Spent Shale		20 cm Soil Cover/ Paraho		40 cm Soil Cover/ Paraho		Soil Control	
	L2	L4	L6	L8	L10	L12	L22	L24
Surface	1.3*	1.4	0.9	0.8	1.5	1.2	1.0	1.9
20	3.2	3.0	1.4	0.8	0.6	0.5	0.7	0.4
40	5.0	5.5	4.6		0.7	0.5	0.6	0.4
60		6.2	6.2	7.4	6.6	2.5	0.5	0.4
80	7.4	6.1	5.9	5.0	8.4	3.2	0.6	0.4
100		5.6	7.2	4.6	9.0	4.5	0.7	0.5
120	7.4	6.2	6.8		10.4	5.4	0.9	0.5
140		6.0	6.8	6.6	9.4	7.6	---	1.0
160	7.0	6.0	6.6	--	10.0	12.2	--	1.3

Depth (cm)	25% Slope - South Aspect							
	Paraho Spent Shale		20 cm Soil Cover/ Paraho		40 cm Soil Cover/ Paraho		Soil Control	
	L1	L3	L5	L7	L9	L11	L21	L23
Surface	1.9	1.0	1.1	0.8	0.7	0.7	1.5	0.9
20	2.0		0.7	0.7	0.6	0.6	0.6	0.5
40	3.4	4.7	5.0	4.3	0.7	0.7	0.6	0.5
60	8.6	5.8	9.0	6.0	--	7.0	0.6	0.6
80	6.6		8.0	6.7	10.1	8.0	0.6	0.6
100	6.1	5.5	7.4	7.0	10.0	8.5	0.8	0.5
120	7.7	4.7	5.1	5.7	19.0	--	1.7	--
140	7.9	--	8.6	7.1	18.0	--	2.2	--
160	6.6	5.5	8.2	6.2	11.6	--	0.7	--

* EC values are in mmhos/cm @25°C measured on a 1:1 spent shale or soil to water by weight sample.

-- No sample collected.

APPENDIX TABLE 19. VEGETATIVE ANALYSIS (TRANSECT METHOD) OF THE HIGH-ELEVATION LYSIMETER, SOUTH-ASPECT, 25% SLOPE TREATMENTS, 1980.

Species	High-Elevation Lysimeters, South Aspect											
	Paraho Retorted Shale		20 cm Soil/ Paraho		40 cm Soil/ Paraho		60 cm Soil/ Paraho		80 cm Soil/ Paraho		Soil Control	
	H1	H3	H5	H7	H9	H11	H13	H15	H17	H19	H21	H23
PERENNIAL GRASSES												
Western wheatgrass	13*	34	313	309	445	180	290	278	334	457	244	100
Bluebunch wheatgrass	-	-	103	211	129	197	140	114	38	124	80	164
Galleta	-	-	-	-	-	-	-	-	-	-	-	-
Crested wheatgrass	-	-	-	-	-	-	-	-	-	-	-	-
Indian ricegrass	-	-	-	-	-	-	-	-	-	-	-	-
Intermediate wheatgrass	-	-	-	-	-	-	-	-	-	-	-	-
SHRUBS												
Fourwing saltbush	-	-	-	-	-	-	-	-	-	-	-	-
Winterfat	-	-	-	-	-	-	-	-	-	-	-	-
Rabbitbrush	-	-	-	-	-	-	-	-	-	-	-	-
Big sage	-	-	-	-	-	-	-	-	-	-	-	-
FORBS												
Utah sweetvetch	-	-	3	3	5	4	-	-	-	-	-	-
OTHER SPECIES												
Cheatgrass	10	2	127	52	179	155	161	109	181	32	34	2
Kochia	368	387	-	-	-	-	-	-	-	-	-	-
Mustard	-	-	-	-	-	-	-	-	-	-	-	-
Russian thistle	-	5	-	-	-	-	-	-	-	-	-	-
Salt cedar	-	22	-	-	-	-	-	-	-	-	-	-
Alfalfa	-	-	-	-	-	-	-	-	-	-	-	-
Sticktight	-	-	-	-	-	-	-	-	-	-	-	-
Gumweed	-	-	-	-	-	-	-	-	-	-	-	-
Prickly lettuce	-	-	-	-	-	-	-	-	-	-	-	-
Plantain	-	-	-	-	-	-	-	-	4	-	-	-
NO VEGETATIVE COVER	347	511	64	72	78	53	11	135	165	30	13	8
LITTER	301	104	469	360	314	490	470	436	306	469	645	756

* Values are total centimeters of aboveground vegetative cover by species. Each plot represents a total of three transect lines approximately 350 cm in length each. Line 1 in upper, line 2 in middle, and line 3 in lower 1/3 of each plot.

APPENDIX TABLE 20. VEGETATIVE ANALYSIS (TRANSECT METHOD) OF THE HIGH-ELEVATION LYSIMETER, NORTH-ASPECT, 2% SLOPE TREATMENT, 1980.

Species	High-Elevation Lysimeters, North Aspect											
	Paraho Retorted Shale		20 cm Soil/ Paraho		40 cm Soil/ Paraho		60 cm Soil/ Paraho		80 cm Soil/ Paraho		Soil Control	
	H2	H4	H6	H8	H10	H12	H14	H16	H18	H20	H22	H24
PERENNIAL GRASSES												
Western wheatgrass	-	27*	269	134	138	156	354	265	137	266	166	277
Bluebunch wheatgrass	29	-	99	130	180	189	138	126	110	95	93	108
Galleta	-	-	-	-	-	-	-	-	-	-	-	-
Crested wheatgrass	-	-	-	-	-	-	-	-	-	-	-	-
Indian ricegrass	-	-	-	-	-	-	-	-	-	-	-	-
Intermediate wheatgrass	-	-	-	-	-	-	-	-	-	-	38	-
SHRUBS												
Fourwing saltbush	-	-	-	-	-	-	-	-	-	-	-	-
Winterfat	-	-	-	-	-	-	-	-	-	-	-	-
Rabbitbrush	-	-	-	-	-	-	-	-	-	-	-	-
Big sage	-	-	-	-	-	-	-	-	-	-	-	-
FORBS												
Utah sweetvetch	-	-	-	9	-	-	-	-	-	-	-	6
OTHER SPECIES												
Cheatgrass	43	-	195	110	148	109	380	105	200	224	-	-
Kochia	436	489	-	-	-	-	-	-	-	-	-	-
Mustard	-	-	-	-	-	-	-	-	-	-	-	-
Russian thistle	-	-	-	-	-	-	-	-	-	-	-	-
Salt cedar	-	-	-	-	-	-	-	-	-	-	-	-
Alfalfa	-	-	-	-	-	-	-	-	-	-	-	-
Sticktight	-	-	-	-	-	-	-	-	-	-	-	-
Gumweed	-	-	-	-	-	-	-	-	-	-	-	-
Prickly lettuce	-	-	-	-	-	-	-	-	-	-	-	-
Plantain	-	-	-	-	-	-	-	-	-	22	-	-
NO VEGETATIVE COVER	253	298	23	47	67	22	62	30	62	65	25	9
LITTER	317	197	459	573	526	590	294	537	516	438	716	631

* Values are total centimeters of aboveground vegetative cover by species. Each plot represents a total of three transect lines approximately 350 cm in length each. Line 1 in upper, line 2 in middle, and line 3 in lower 1/3 of each plot.

APPENDIX TABLE 21. VEGETATIVE ANALYSIS (TRANSECT METHOD) OF THE LOW-ELEVATION LYSIMETER, SOUTH-ASPECT, 25% SLOPE TREATMENTS, 1980.

Species	Low-Elevation Lysimeters, South Aspect											
	Paraho Retorted Shale		20 cm Soil/ Paraho		40 cm Soil/ Paraho		60 cm Soil/ Paraho		80 cm Soil/ Paraho		Soil Control	
	L1	L3	L5	L7	L9	L11	L13	L15	L17	L19	L21	L23
PERENNIAL GRASSES												
Western wheatgrass	-	-	113*	74	37	-	-	27	4	6	123	100
Bluebunch wheatgrass	-	-	-	-	3	-	-	-	-	-	8	-
Galleta	-	-	164	102	153	156	134	83	115	148	139	70
Crested wheatgrass	-	-	3	-	-	-	-	-	-	-	-	-
Indian ricegrass	-	-	-	6	-	-	-	-	-	-	-	-
Intermediate wheatgrass	-	-	-	-	-	-	-	-	-	-	-	-
SHRUBS												
Fourwing saltbush	66	-	-	-	23	9	-	-	13	-	67	127
Winterfat	-	-	-	-	-	-	-	-	-	3	-	12
Rabbitbrush	-	-	-	-	-	-	-	-	-	-	-	-
Big sage	-	-	-	-	-	-	-	-	-	-	-	-
FORBS												
Utah sweetvetch	-	-	-	-	-	-	-	-	-	-	-	-
OTHER SPECIES												
Cheatgrass	8	14	282	467	545	385	402	439	466	426	118	271
Kochia	184	163	-	-	-	-	-	-	-	-	-	-
Mustard	-	-	4	2	7	6	7	5	2	4	13	2
Russian thistle	4	8	-	-	-	-	-	-	-	-	-	-
Salt cedar	-	-	-	-	-	-	-	-	-	-	-	-
Alfalfa	-	-	-	-	-	-	-	-	-	-	-	-
Sticktight	2	-	-	-	-	-	-	-	-	-	-	-
Gumweed	-	-	-	-	-	-	-	-	-	-	-	-
Prickly lettuce	-	-	-	-	-	-	-	-	-	-	-	-
Plantain	-	-	-	-	-	-	-	-	-	-	-	-
NO VEGETATIVE COVER	434	677	50	77	116	38	30	29	51	47	56	29
LITTER	313	237	258	305	198	435	468	433	373	499	491	480

* Values are total centimeters of aboveground vegetative cover by species. Each plot represents a total of three transect lines approximately 350 cm in length each. Line 1 in upper, line 2 in middle, and line 3 in lower 1/3 of each plot.

APPENDIX TABLE 22. VEGETATIVE ANALYSIS (TRANSECT METHOD) OF THE LOW-ELEVATION LYSIMETER, NORTH-ASPECT, 2% SLOPE TREATMENTS, 1980.

Species	Low-Elevation Lysimeters, North Aspect											
	Paraho Retorted Shale		20 cm Soil/ Paraho		40 cm Soil/ Paraho		60 cm Soil/ Paraho		80 cm Soil/ Paraho		Soil Control	
	L2	L4	L6	L8	L10	L12	L14	L16	L18	L20	L22	L24
PERENNIAL GRASSES												
Western wheatgrass	2*	5	84	55	130	55	112	40	169	39	65	138
Bluebunch wheatgrass	-	-	7	-	-	7	-	3	-	96	11	98
Galleta	-	-	-	-	-	49	67	31	90	129	34	56
Crested wheatgrass	-	-	-	-	-	-	-	-	-	-	-	-
Indian ricegrass	-	-	-	3	-	-	6	-	-	-	-	-
Intermediate wheatgrass	-	-	-	-	-	-	-	-	-	-	-	-
SHRUBS												
Fourwing saltbush	9	14	11	3	-	-	29	15	38	36	-	15
Winterfat	-	6	-	-	-	-	2	-	-	-	-	28
Rabbitbrush	-	-	4	-	-	-	-	-	-	-	-	-
Big sage	-	-	-	-	-	-	-	-	-	-	11	-
FORBS												
Utah sweetvetch	-	-	-	-	-	-	-	-	-	-	-	-
OTHER SPECIES												
Cheatgrass	-	11	703	540	568	621	486	539	358	317	478	101
Kochia	277	171	-	-	-	-	-	-	-	-	-	-
Mustard	-	-	-	-	-	-	-	-	6	10	7	-
Russian thistle	-	9	-	-	-	-	-	-	-	-	-	-
Salt cedar	-	8	-	-	-	-	-	-	-	-	-	-
Alfalfa	-	2	-	2	4	-	-	2	-	-	-	-
Sticktight	-	-	-	-	-	-	-	-	-	-	-	-
Gumweed	-	-	5	-	-	-	-	-	-	-	-	-
Prickly lettuce	-	-	-	-	-	-	-	-	-	-	-	-
Plantain	-	-	-	-	-	-	-	-	-	-	-	-
NO VEGETATIVE COVER	580	556	36	47	41	34	73	36	73	177	22	112
LITTER	121	212	225	235	303	281	312	368	329	306	385	428

* Values are total centimeters of aboveground vegetative cover by species. Each plot represents a total of three transect lines approximately 350 cm in length each. Line 1 in upper, line 2 in middle, and line 3 in lower 1/3 of each plot.

APPENDIX TABLE 23. MOISTURE MEASUREMENTS (NEUTRON PROBE) FROM THE HIGH-ELEVATION LYSIMETER, SOUTH-ASPECT, 25% SLOPE TREATMENTS, 1980.

Depth (cm)	Paraho Spent Shale										20 cm Soil Cover/Paraho									
	H1					H3					H5					H7				
	4/14	5/27	6/20	8/19	10/4	4/14	5/27	6/20	8/19	10/4	4/14	5/27	6/20	8/19	10/4	4/14	5/27	6/20	8/19	10/4
15	19.5	19.5	2.8	9.8	1.3	22.5	22.0	2.8	7.5	1.3	19.5	11.5	2.8	7.3	2.0	22.0	13.8	3.3	7.5	1.0
30	19.0	19.0	12.3	1.3	7.3	22.5	22.5	13.3	1.3	8.3	20.8	14.8	8.8	1.3	6.3	21.3	16.0	9.3	1.5	6.5
45	17.8	19.0	15.5	5.3	10.5	19.5	16.5	17.8	8.5	14.0	22.5	19.5	11.3	6.3	9.0	22.0	19.0	9.8	7.0	9.8
60	16.5	17.8	15.0	9.8	12.5	17.0	16.0	17.8	13.5	15.0	22.0	18.3	13.3	8.8	12.8	20.8	19.5	14.5	8.5	11.8
75	16.5	16.5	15.0	11.3	12.5	15.5	16.0	13.3	15.0	13.5	14.8	12.8	15.5	10.8	12.8	18.3	16.5	16.0	10.5	12.8
90	17.8	19.5	15.5	12.8	13.0	17.0	17.8	13.3	13.5	12.5	10.5	10.0	11.3	14.5	11.8	19.0	17.0	15.0	12.0	12.8
105	21.8	22.8	16.5	12.8	13.5	19.0	19.0	14.5	12.0	12.0	10.5	9.5	9.3	11.8	8.5	20.8	18.3	14.5	13.5	12.3
120	23.0	-	20.0	13.3	15.0	22.0	20.8	16.0	12.0	13.0	16.0	-	9.3	8.8	7.0	20.8	18.3	15.0	12.5	12.8
135	-	-	-	17.3	17.3	-	-	19.0	13.5	13.5	-	-	14.5	7.8	8.0	-	-	17.3	12.5	14.0
150	-	-	-	18.3	-	-	-	-	14.0	15.0	-	-	-	8.8	-	-	-	17.8	13.0	14.5

Depth (cm)	40 cm Soil Cover/Paraho										60 cm Soil Cover/Paraho									
	H9					H11					H13					H15				
	4/14	5/27	6/20	8/19	10/4	4/14	5/27	6/20	8/19	10/4	4/14	5/27	6/20	8/19	10/4	4/14	5/27	6/20	8/19	10/4
15	18.3	11.5	2.5	7.5	1.3	21.8	14.3	2.5	9.8	1.3	22.0	12.8	2.8	7.3	1.0	23.0	14.5	2.8	9.0	2.0
30	21.3	16.0	8.3	1.3	5.5	21.3	16.0	9.0	1.3	5.5	22.5	16.0	8.8	1.8	6.3	22.5	16.5	9.3	1.5	6.3
45	23.0	20.8	9.8	6.0	8.3	20.0	17.0	10.5	6.8	8.8	22.5	17.8	11.3	7.8	9.0	23.8	18.3	11.3	7.5	9.0
60	24.3	22.5	12.3	9.0	10.0	16.5	16.0	11.0	8.8	9.3	21.3	19.0	11.8	9.8	9.0	24.5	20.8	11.3	9.5	9.3
75	22.5	20.8	16.0	9.5	12.5	17.3	15.3	11.5	9.3	9.8	22.0	19.0	12.3	10.3	9.0	24.5	21.3	12.3	9.5	9.3
90	20.8	19.0	15.5	11.5	13.0	16.5	15.3	13.3	9.8	10.5	21.3	18.3	15.0	10.3	10.8	24.5	20.0	15.5	9.5	11.8
105	20.0	19.0	15.5	14.0	14.0	17.8	17.8	14.8	10.8	11.0	20.8	19.5	15.5	10.8	12.8	22.0	19.0	18.3	11.5	13.0
120	17.8	17.0	16.5	13.5	13.5	-	-	15.5	11.3	11.0	21.3	19.5	17.8	12.8	13.5	20.8	17.8	16.5	13.5	13.0
135	-	-	16.0	13.5	14.0	-	-	17.0	12.3	13.0	-	-	17.8	13.8	14.5	19.0	17.3	16.5	14.5	14.0
150	-	-	-	14.0	13.0	-	-	-	12.8	-	-	-	18.3	15.0	14.5	-	-	16.5	15.0	13.5

Depth (cm)	80 cm Soil Cover/Paraho										Soil Control									
	H17					H19					H21					H23				
	4/14	5/27	6/20	8/19	10/4	4/14	5/27	6/20	8/19	10/4	4/14	5/27	6/20	8/19	10/4	4/14	5/27	6/20	8/19	10/4
15	19.0	12.8	2.8	7.5	1.0	19.5	13.0	1.5	7.8	1.3	18.3	13.8	3.3	8.3	1.3	17.8	11.3	3.0	8.8	1.3
30	21.3	14.5	9.3	1.3	5.3	22.0	17.0	7.8	1.3	5.5	23.0	18.3	10.3	1.3	6.3	23.0	17.0	9.5	1.3	5.5
45	23.0	17.8	10.8	5.8	9.3	22.5	17.8	10.3	5.8	8.3	24.5	20.8	12.8	7.8	9.8	24.5	22.0	11.5	5.8	8.3
60	23.0	19.0	12.8	9.5	10.8	23.8	19.5	10.8	8.8	9.3	25.8	22.5	13.3	9.8	11.0	27.0	24.5	13.8	8.8	9.3
75	22.5	20.0	13.3	10.5	10.8	23.0	20.0	11.3	9.8	9.3	26.5	25.0	14.0	10.8	12.0	27.8	25.3	13.8	10.3	10.0
90	22.0	20.0	15.5	12.0	11.0	23.8	22.8	11.8	10.3	10.0	24.5	23.0	15.0	11.8	11.5	25.8	24.5	13.8	10.8	10.0
105	22.0	20.8	17.3	11.5	13.0	20.8	20.0	17.3	10.3	13.0	23.8	22.5	15.0	12.3	11.0	22.5	24.0	13.3	11.3	9.3
120	20.8	20.0	18.3	12.5	14.5	17.0	17.8	17.3	12.8	14.0	21.3	22.0	15.5	12.3	10.5	17.0	17.8	13.3	10.8	8.8
135	-	-	18.3	13.5	15.0	18.3	19.0	16.0	13.8	13.5	17.0	20.8	16.5	11.8	11.0	-	-	12.8	9.3	8.3
150	-	-	-	15.0	13.5	-	-	17.3	13.8	13.5	-	-	16.0	11.8	11.0	-	-	-	9.3	-

APPENDIX TABLE 24. MOISTURE MEASUREMENTS (NEUTRON PROBE) FROM THE HIGH-ELEVATION LYSIMETER, NORTH-ASPECT, 2% SLOPE TREATMENTS, 1980.

Depth (cm)	Paraho Spent Shale										20 cm Soil Cover/Paraho									
	H2					H4					H6					H8				
	4/14	5/27	6/20	8/19	10/4	4/14	5/27	6/20	8/19	10/4	4/14	5/27	6/20	8/19	10/4	4/14	5/27	6/20	8/19	10/4
15	14.0	12.0	2.5	7.8	1.3	20.0	17.8	3.5	7.0	2.0	18.3	10.5	2.5	9.0	1.0	18.3	10.3	2.5	7.5	1.0
30	17.8	17.8	12.8	0.3	7.3	15.5	14.5	11.5	1.3	8.5	22.0	16.5	9.0	1.3	6.3	20.8	14.5	7.8	1.3	9.0
45	17.8	16.3	13.8	5.8	11.0	9.8	9.3	12.0	8.5	10.3	21.3	19.5	14.3	6.5	11.0	20.8	10.8	11.3	7.5	9.8
60	17.3	16.3	16.0	9.8	11.5	8.3	8.3	9.5	10.5	8.0	15.5	14.8	15.5	9.5	12.8	14.5	12.8	12.8	8.5	9.8
75	21.3	19.5	16.0	11.8	13.0	9.3	9.3	8.0	8.5	6.3	14.8	13.8	14.3	12.5	11.0	10.3	9.3	11.3	10.5	9.0
90	21.3	21.3	20.8	12.8	16.0	14.0	12.8	9.0	6.0	6.3	14.3	12.8	12.8	12.5	11.0	11.3	9.8	10.3	11.0	8.0
105	22.5	20.5	21.3	16.0	16.5	17.3	16.5	12.0	6.5	9.0	13.3	13.3	12.0	11.5	9.8	17.3	16.5	9.3	9.0	9.0
120	22.5	19.5	22.5	17.3	17.8	-	-	16.5	8.5	11.8	-	-	12.8	10.5	9.3	-	-	13.3	8.0	13.5
135	21.8	19.5	20.8	18.3	17.3	-	-	-	12.0	-	-	-	-	9.5	9.8	-	-	22.5	8.5	16.8
150	-	-	20.8	17.3	16.5	-	-	-	-	-	-	-	-	10.5	-	-	-	-	16.5	-

Depth (cm)	40 cm Soil Cover/Paraho										60 cm Soil Cover/Paraho									
	H10					H12					H14					H16				
	4/14	5/27	6/20	8/19	10/4	4/14	5/27	6/20	8/19	10/4	4/14	5/27	6/20	8/19	10/4	4/14	5/27	6/20	8/19	10/4
15	22.0	11.5	2.8	8.0	1.0	22.0	12.3	2.5	7.3	1.3	22.5	11.5	2.5	8.5	1.3	22.5	14.3	2.0	7.5	1.3
30	22.5	14.8	9.8	0.8	6.3	22.0	14.0	9.3	0.8	6.3	22.5	13.8	7.8	0.8	5.5	23.8	19.0	9.5	1.3	6.3
45	20.8	16.0	9.8	7.0	8.0	22.0	18.3	10.3	7.8	8.3	21.3	16.3	10.3	6.5	8.8	23.0	20.8	11.0	6.0	8.8
60	19.5	18.3	10.3	9.0	9.0	22.5	20.8	11.3	9.3	9.3	18.3	15.5	10.3	8.0	8.8	20.8	19.0	11.5	9.0	9.3
75	20.8	20.8	14.5	9.0	9.8	20.8	17.3	14.0	9.3	10.5	16.5	15.5	9.8	8.5	8.8	18.3	17.0	12.0	9.0	9.3
90	20.8	20.8	16.0	9.5	12.8	1a.0	15.0	14.5	10.8	11.5	14.5	14.8	10.8	9.5	8.8	12.8	11.5	12.8	9.0	9.3
105	22.5	21.3	19.0	12.0	14.5	18.3	16.0	13.3	12.3	11.5	15.5	14.8	11.3	8.5	9.3	12.8	11.0	12.0	8.5	9.8
120	-	-	20.0	15.5	15.5	20.8	20.0	16.0	11.8	11.5	17.8	18.3	12.8	9.5	10.0	13.8	13.8	11.0	9.5	8.8
135	-	-	-	16.0	16.8	-	-	17.8	12.8	14.0	-	-	13.3	9.5	12.0	-	-	12.0	8.5	8.8
150	-	-	-	-	-	-	-	-	14.5	15.0	-	-	-	11.0	14.0	-	-	-	9.0	11.5

Depth (cm)	80 cm Soil Cover/Paraho										Soil Control									
	H18					H20					H22					H24				
	4/14	5/27	6/20	8/19	10/4	4/14	5/27	6/20	8/19	10/4	4/14	5/27	6/20	8/19	10/4	4/14	5/27	6/20	8/19	10/4
15	15.5	9.3	3.0	9.0	1.0	10.5	5.0	2.0	6.8	1.3	16.0	10.5	2.5	7.5	1.3	12.8	10.0	2.5	8.8	1.3
30	20.8	14.5	9.0	1.3	5.3	20.8	13.8	8.5	0.8	5.5	23.0	20.8	10.0	1.3	6.3	20.8	18.3	10.0	1.3	4.5
45	21.3	16.5	10.5	6.5	7.5	22.5	16.5	10.5	6.3	7.3	24.3	23.0	12.8	6.5	10.0	21.8	20.8	11.5	6.8	7.3
60	22.5	17.3	11.0	8.5	8.5	22.5	18.3	11.5	7.8	9.8	23.8	23.0	13.8	10.0	11.0	23.0	22.0	13.3	8.8	8.3
75	20.0	18.3	12.0	9.0	9.3	22.0	18.3	11.5	9.3	9.3	22.5	22.5	14.3	10.5	10.5	20.0	21.3	15.5	9.8	9.3
90	20.0	17.8	13.3	9.5	9.8	19.0	17.0	11.0	9.3	8.8	20.0	21.3	14.8	11.0	11.0	14.5	19.5	16.5	10.3	10.0
105	17.8	15.0	14.8	10.0	11.8	20.8	20.8	12.8	9.3	9.3	17.8	19.5	16.0	11.5	11.0	12.8	13.3	16.0	10.8	9.8
120	16.0	15.5	14.8	11.0	11.8	19.5	-	15.5	9.3	11.0	17.3	17.0	16.0	11.5	11.0	12.3	11.5	12.8	10.8	9.8
135	-	-	16.0	12.0	11.8	-	-	-	12.3	-	15.5	16.0	15.5	11.0	11.0	12.3	12.8	12.0	9.8	10.5
150	-	-	-	12.0	-	-	-	-	-	-	14.5	14.8	14.8	11.5	11.0	-	-	12.8	10.3	10.0

APPENDIX TABLE 25. MOISTURE MEASUREMENTS (NEUTRON PROBE) FROM THE LOW-ELEVATION LYSIMETER, SOUTH-ASPECT, 25% SLOPE TREATMENTS, 1980.

Depth (cm)	Paraho Spent Shale										20 cm Soil Cover/Paraho									
	L1					L3					L5					L7				
	4/14	5/28	6/19	8/19	10/4	4/14	5/28	6/19	8/19	10/4	4/14	5/28	6/19	8/19	10/4	4/14	5/28	6/19	8/19	10/4
15	12.8	8.8	2.5	0.8	1.0	19.0	17.8	2.5	1.3	1.0	6.5	2.8	2.0	1.3	1.3	16.0	10.5	2.0	1.3	1.0
30	14.3	14.5	8.3	2.0	2.0	22.0	20.0	9.5	5.8	6.3	17.0	9.8	7.8	7.3	5.5	20.8	14.3	8.5	5.8	5.0
45	16.0	15.5	10.3	4.8	4.5	22.0	20.8	11.0	12.3	11.0	20.8	14.5	10.3	10.5	9.3	22.0	17.0	11.5	9.0	8.5
60	19.0	16.0	10.8	8.5	9.0	22.5	21.3	11.0	14.5	12.8	20.8	17.8	10.3	12.0	11.5	22.5	20.8	11.5	13.0	14.0
75	19.0	18.3	13.3	12.5	11.8	22.5	21.3	11.5	16.5	14.0	16.5	14.5	10.3	11.5	11.5	21.3	18.3	13.8	15.5	14.5
90	20.8	19.0	13.3	14.0	12.8	22.0	21.3	10.5	17.3	14.5	14.8	12.3	11.3	9.3	10.0	22.0	20.8	16.0	15.5	14.5
105	20.8	19.0	-	15.0	14.0	22.0	21.8	10.0	16.0	15.0	14.3	12.3	13.3	9.8	9.8	22.5	21.3	17.0	14.5	14.5
120	19.0	17.8	-	16.0	14.5	23.0	20.8	11.5	17.3	15.5	14.8	15.5	15.5	11.0	10.0	22.0	21.3	15.5	16.5	16.5
135	19.0	-	-	15.0	14.5	23.0	-	10.5	18.3	15.5	16.0	-	15.0	12.0	11.0	22.0	-	16.0	16.5	15.5
150	-	-	-	-	14.5	-	-	-	17.3	15.0	-	-	12.8	-	-	-	-	-	17.8	15.5

Depth (cm)	40 cm Soil Cover/Paraho										60 cm Soil Cover/Paraho									
	L9					L11					L13					L15				
	4/14	5/28	6/19	8/19	10/4	4/14	5/28	6/19	8/19	10/4	4/14	5/28	6/19	8/19	10/4	4/14	5/28	6/19	8/19	10/4
15	12.8	7.5	2.5	2.0	1.0	16.0	10.5	2.0	1.5	1.0	17.0	8.8	2.5	1.3	1.3	17.0	11.5	2.5	1.3	1.0
30	20.8	12.8	7.3	8.0	6.3	20.8	18.3	7.5	5.8	3.5	19.5	11.3	8.5	6.5	4.5	20.8	14.8	9.5	6.5	4.0
45	20.8	14.8	10.8	9.5	8.0	22.0	20.8	10.5	9.5	7.0	21.3	13.3	11.5	9.0	7.3	22.0	16.5	11.0	9.0	7.5
60	22.5	19.5	10.8	11.0	11.0	22.5	20.8	11.5	9.0	9.0	22.0	16.5	14.3	9.5	9.3	22.5	18.3	14.3	9.5	9.0
75	23.0	19.0	13.3	13.5	12.8	23.8	21.3	13.8	11.5	10.8	18.3	16.0	17.0	10.5	10.0	22.5	19.0	17.0	11.5	10.3
90	23.0	19.5	15.5	13.0	13.5	22.0	19.5	14.3	14.0	12.8	17.0	14.5	17.0	10.5	10.0	21.3	19.5	17.8	13.0	10.8
105	22.0	19.0	16.0	15.5	14.0	20.8	19.5	13.3	14.0	12.8	15.5	14.0	17.0	10.5	10.0	20.8	18.3	18.3	13.5	12.3
120	20.8	18.3	16.5	15.5	15.0	20.8	18.3	13.8	13.5	12.8	14.8	14.0	17.8	10.0	9.3	20.8	-	17.8	13.5	12.8
135	20.8	-	-	15.5	14.5	20.8	-	13.8	15.0	13.5	-	-	17.0	10.5	10.0	-	-	18.3	14.0	11.8
150	-	-	-	15.0	14.5	-	-	-	15.5	14.0	-	-	18.3	-	10.5	-	-	-	-	-

Depth (cm)	80 cm Soil Cover/Paraho										Soil Control									
	L17					L19					L21					L23				
	4/14	5/28	6/19	8/19	10/4	4/14	5/28	6/19	8/19	10/4	4/14	5/28	6/19	8/19	10/4	4/14	5/28	6/19	8/19	10/4
15	17.8	10.5	2.5	0.8	1.0	16.5	9.0	2.0	1.3	1.0	16.5	8.8	3.0	1.5	1.3	11.5	6.3	1.0	0.8	1.3
30	22.5	16.0	7.5	6.0	3.5	19.5	14.5	7.8	6.0	3.5	20.8	15.5	13.8	6.5	4.5	19.5	12.8	4.0	5.8	3.8
45	23.0	16.5	11.5	9.0	7.5	22.0	16.3	12.3	8.5	7.0	22.5	17.3	12.0	9.0	7.8	21.3	15.5	9.0	9.0	7.8
60	22.5	18.3	16.5	10.5	9.3	21.3	16.3	14.5	8.5	8.0	21.3	19.0	18.3	8.5	7.3	21.3	16.5	13.8	9.0	8.8
75	22.5	19.5	18.3	10.5	9.8	19.5	16.3	12.8	9.0	8.0	19.0	17.3	18.3	8.5	7.8	23.0	18.3	16.0	9.5	8.8
90	21.3	19.5	17.0	11.0	10.3	17.0	15.3	11.3	9.0	8.0	16.5	15.0	19.0	8.0	7.3	20.8	18.3	16.5	11.0	10.0
105	19.5	17.0	18.3	13.0	10.8	17.0	15.8	11.8	10.5	9.0	13.3	13.3	20.8	7.5	6.8	22.0	-	18.3	10.5	9.8
120	17.0	16.5	20.8	13.0	11.8	14.8	15.8	14.5	11.5	10.3	11.3	10.3	19.5	8.0	7.3	-	-	18.3	10.0	-
135	-	-	20.8	12.0	11.0	11.5	13.5	14.5	12.5	10.8	10.3	-	19.5	8.5	8.3	-	-	17.8	-	-
150	-	-	-	12.5	11.0	-	-	-	11.5	10.8	-	-	-	8.0	8.3	-	-	-	-	-

APPENDIX TABLE 26. MOISTURE MEASUREMENTS (NEUTRON PROBE) FROM THE LOW-ELEVATION LYSIMETER, NORTH-ASPECT, 2% SLOPE TREATMENTS, 1980.

Depth (cm)	Paraho Spent Shale										20 cm Soil Cover/Paraho									
	L2					L4					L6					L8				
	4/14	5/28	6/19	8/19	10/4	4/14	5/28	6/19	8/19	10/4	4/14	5/28	6/19	8/19	10/4	4/14	5/28	6/19	8/19	10/4
15	17.0	15.5	2.5	0.8	1.0	20.8	17.0	2.5	1.3	1.3	20.8	16.0	2.5	1.3	1.0	12.8	7.3	2.0	1.5	1.3
30	17.8	16.5	9.3	5.0	5.3	18.3	17.0	11.5	6.5	6.8	20.8	17.8	9.3	5.8	4.5	23.8	19.0	9.3	6.5	6.3
45	17.8	16.0	13.3	9.8	9.8	15.5	16.0	14.8	11.0	11.5	19.5	17.8	13.3	9.5	10.3	24.5	20.0	15.5	12.0	10.5
60	18.3	17.8	15.0	11.0	11.8	16.5	17.0	14.3	12.0	11.0	16.5	15.5	14.5	12.5	12.8	21.3	20.0	16.5	13.0	13.0
75	20.8	20.0	15.5	12.0	12.3	18.3	18.3	15.5	11.5	12.0	16.5	14.5	14.5	12.5	11.8	19.5	16.5	16.0	14.5	13.0
90	22.0	21.3	17.8	13.5	13.5	18.3	18.3	16.5	13.0	13.0	16.0	15.0	14.0	10.5	10.8	17.8	16.5	15.0	13.0	13.0
105	21.3	21.3	19.0	14.5	14.5	20.8	20.8	16.5	13.5	13.5	-	-	13.3	12.0	10.8	17.0	16.0	14.5	13.0	12.5
120	20.8	19.5	19.5	15.0	15.5	20.8	20.8	19.5	14.0	14.0	-	-	13.3	12.0	11.0	17.8	17.3	15.5	12.5	12.0
135	20.8	-	19.0	16.0	15.5	-	-	19.5	15.5	15.5	-	-	-	-	-	18.3	-	17.3	13.5	13.0
150	-	-	18.3	-	14.5	-	-	-	15.0	15.0	-	-	-	-	-	-	-	-	-	-

Depth (cm)	40 cm Soil Cover/Paraho										60 cm Soil Cover/Paraho									
	L10					L12					L14					L16				
	4/14	5/28	6/19	8/19	10/4	4/14	5/28	6/19	8/19	10/4	4/14	5/28	6/19	8/19	10/4	4/14	5/28	6/19	8/19	10/4
15	19.5	13.3	2.5	1.3	1.3	20.8	15.5	2.5	1.5	1.3	23.0	16.0	1.5	0.8	1.3	17.8	11.3	2.5	1.3	1.3
30	22.0	19.5	8.3	6.8	4.5	21.8	18.3	9.0	6.5	6.0	24.5	20.8	8.0	11.5	3.8	22.5	17.8	7.5	5.3	3.8
45	22.5	19.5	11.3	8.8	8.3	20.8	17.8	11.5	8.5	8.3	23.8	19.0	11.0	8.5	8.3	21.8	19.0	11.0	9.8	7.3
60	20.8	19.0	13.3	9.3	10.0	20.0	17.8	12.8	9.5	9.3	21.3	18.3	12.0	10.0	9.3	20.8	18.3	12.0	9.8	8.3
75	15.5	14.0	14.5	9.8	10.0	19.0	17.3	14.3	10.0	9.8	20.8	18.3	12.8	9.5	9.3	19.0	17.3	12.8	8.8	8.3
90	13.3	12.3	11.8	9.0	8.3	16.5	16.0	16.0	12.5	11.0	17.8	17.0	14.8	10.0	10.0	16.5	15.5	14.3	9.3	8.8
105	13.8	12.8	10.8	8.8	9.3	16.5	16.0	14.8	12.5	11.0	16.0	16.0	16.5	11.5	11.5	15.0	15.5	14.8	10.8	9.8
120	16.5	16.0	12.3	10.3	10.0	20.0	20.8	16.0	12.0	11.0	16.0	16.0	16.5	12.5	12.0	16.5	17.8	14.8	12.3	11.0
135	-	-	14.5	11.8	12.0	21.3	-	19.0	13.5	12.0	14.8	-	16.0	13.0	13.5	17.3	-	16.0	13.3	12.0
150	-	-	-	12.8	-	-	-	22.5	17.3	16.0	-	-	16.0	13.5	13.0	-	-	19.0	16.0	14.0

Depth (cm)	80 cm Soil Cover/Paraho										Soil Control									
	L18					L20					L22					L24				
	4/14	5/28	6/19	8/19	10/4	4/14	5/28	6/19	8/19	10/4	4/14	5/28	6/19	8/19	10/4	4/14	5/28	6/19	8/19	10/4
15	20.8	10.3	2.0	1.3	1.3	21.3	13.3	4.0	2.0	1.5	21.3	14.3	1.5	0.8	1.3	19.0	10.3	1.5	0.8	1.3
30	23.0	15.5	8.0	5.5	3.8	24.5	19.0	9.5	6.5	6.8	21.8	17.0	6.5	5.3	3.3	19.5	13.3	6.5	4.5	4.0
45	23.0	17.8	10.5	6.8	7.3	23.8	19.0	11.5	9.0	9.3	22.5	18.3	9.5	7.5	6.3	19.5	12.8	7.5	6.8	6.3
60	22.0	17.3	10.0	7.3	8.3	22.5	20.0	12.8	8.5	9.3	21.3	17.8	11.0	8.5	8.3	16.0	13.3	7.5	6.0	6.3
75	19.5	17.3	10.5	7.3	7.3	19.0	18.3	13.3	9.5	9.3	20.0	17.8	11.0	9.0	9.3	16.0	13.3	8.5	6.3	6.3
90	17.8	15.5	10.5	6.8	7.3	17.8	16.5	14.8	10.0	9.3	20.0	18.3	11.5	9.5	8.8	13.3	12.3	10.5	7.3	7.8
105	16.0	15.5	14.3	8.8	8.3	16.0	15.5	16.0	10.5	11.0	20.0	18.3	12.8	8.5	9.3	12.8	-	10.5	8.3	8.8
120	14.8	14.5	15.5	11.5	11.0	13.8	12.3	14.8	11.5	11.0	17.8	17.0	14.3	10.0	10.5	-	-	-	8.8	8.8
135	15.5	15.5	16.0	12.0	11.5	13.3	12.3	12.8	9.5	10.0	16.5	-	14.3	10.5	10.5	-	-	-	-	-
150	-	-	15.5	12.0	12.0	-	-	12.0	9.5	9.8	-	-	13.3	10.5	10.5	-	-	-	-	-